New Planet in Pegasus — It's Real

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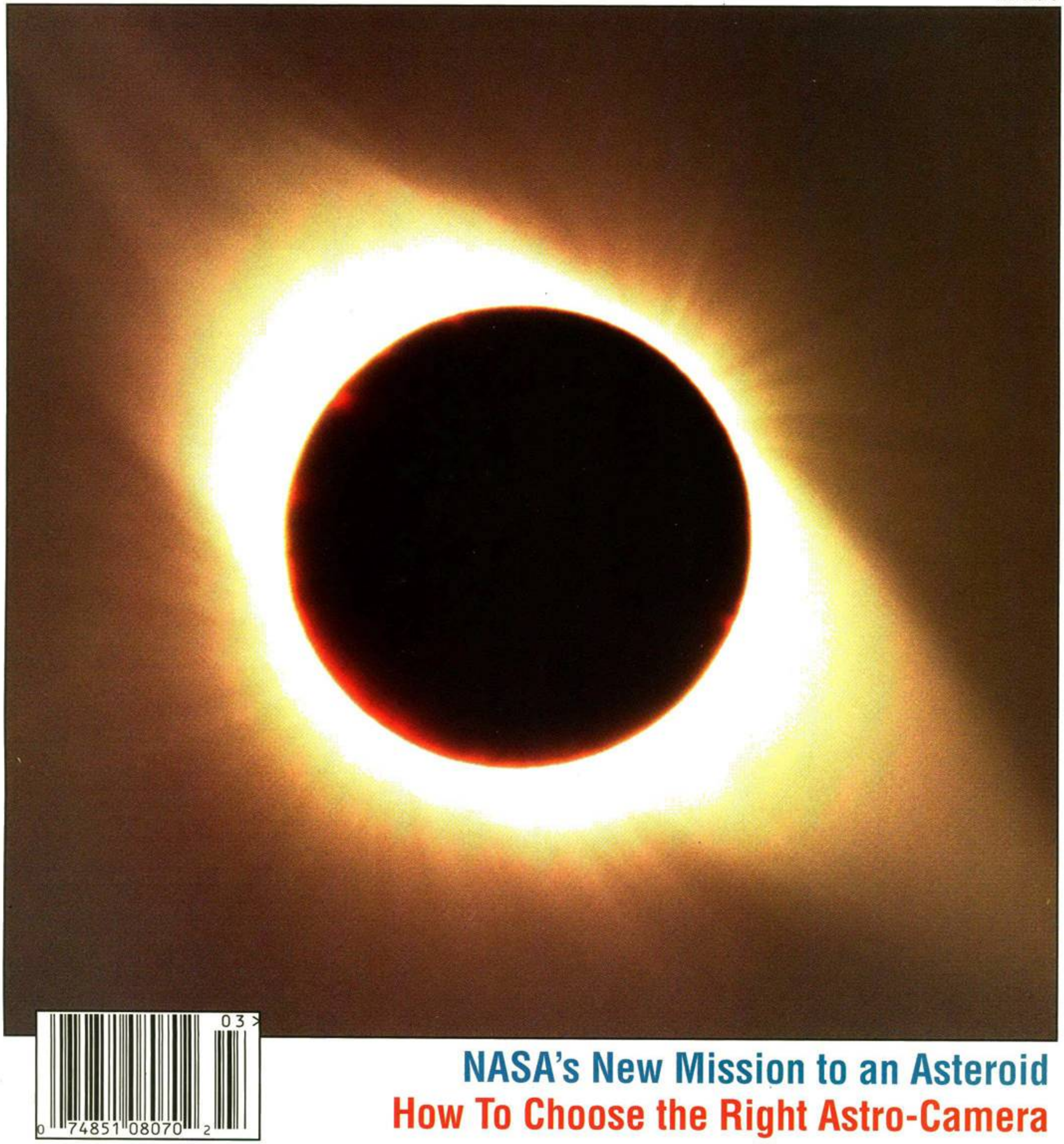

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LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models ***combined***. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of over 64,350 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an auto cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

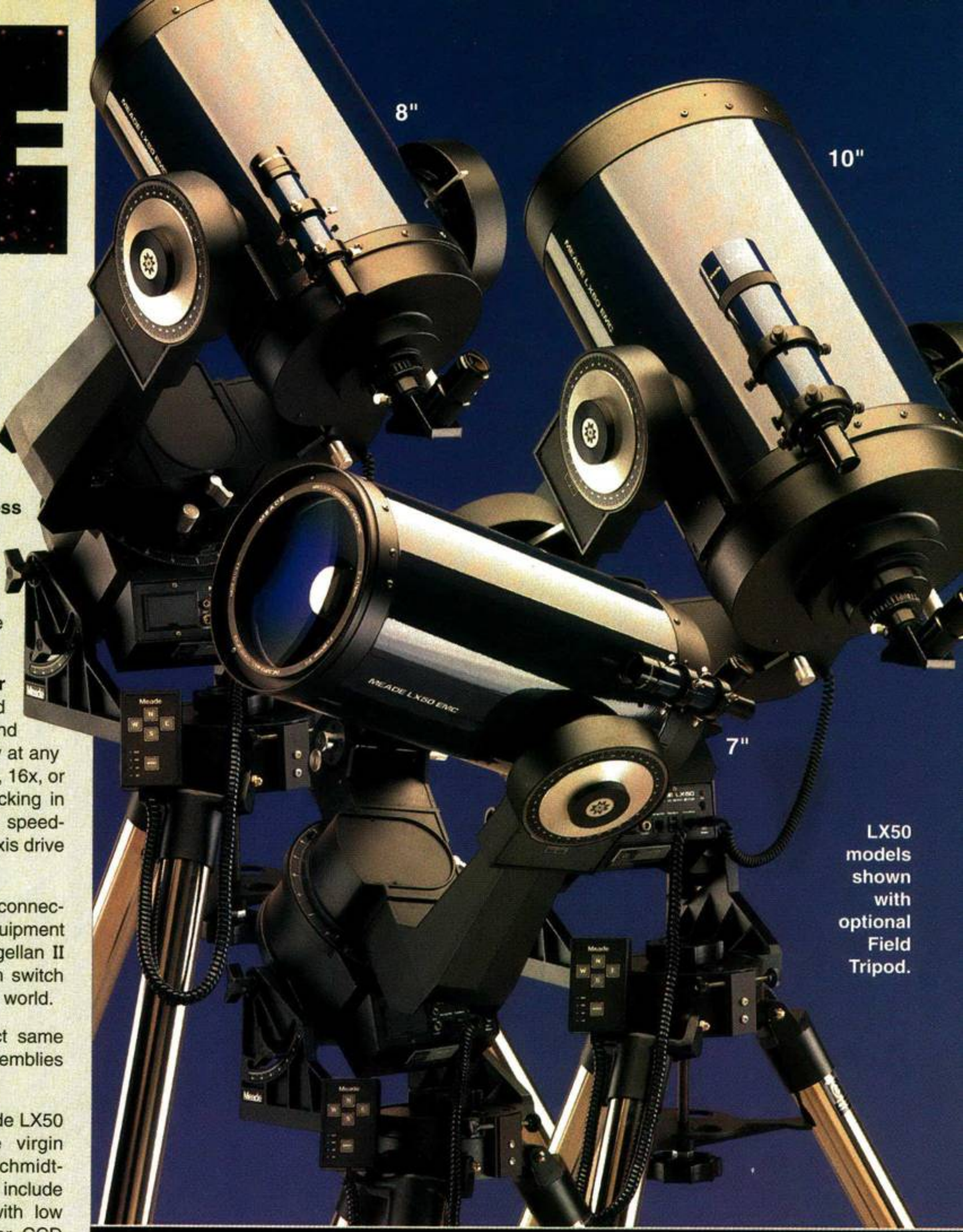
8" LX200 Schmidt-Cassegrain	**$2495.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2995.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

ADE

LX50

Advanced technology at the most affordable prices *ever*.



LX50 models shown with optional Field Tripod.

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from four AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting four (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1195.**
10" LX50 Schmidt-Cassegrain	**1495.**
7" LX50 Maksutov-Cassegrain	**1595.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y, only	**1195.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), completely concealed in special LX50 encoder compartments. ■ Quick 2-star alignment. ■ Large 32-character, red-backlighted display. ■ 4-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$395.** + $15 packing and shipping in the 48 states.

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March 1996
Vol. 24, No. 3

Andrew Peters

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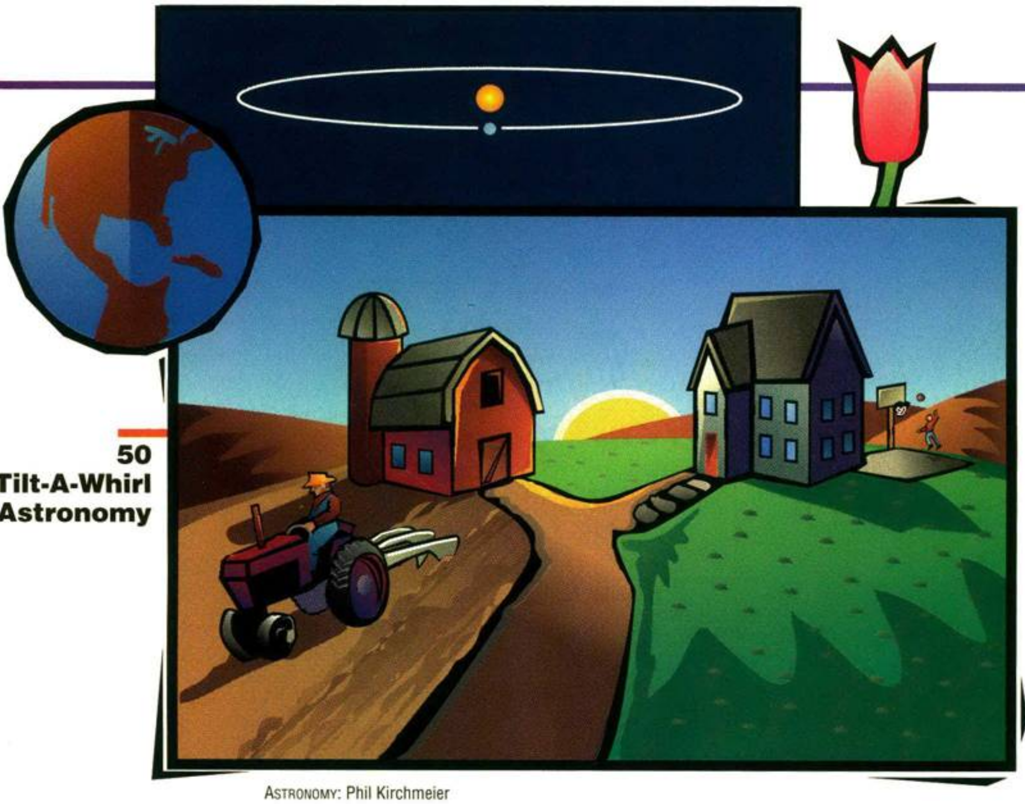

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The Audit Bureau

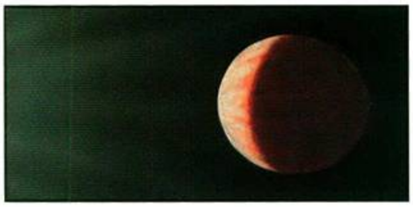
BEHIND THE SCENES

The Mystery Planet

The news trickled into our offices in fragments. First came a tantalizing report that a group of Swiss astronomers had found excellent evidence for a planet orbiting the naked-eye star 51 Pegasi, a Sun-like star 55 to 60 light-years away. The planet had roughly half the mass of Jupiter and, stranger still, it orbited unbelieveably close to 51 Peg — only about 7.5 million kilometers, or eight times closer to its star than Mercury orbits our Sun.

Then an American team with the ideal instrument to verify the discovery showed up for an observing run and promptly dropped their intended research program to check out 51 Peg. They quickly confirmed the findings of the Swiss team (whose original report also included the possibility of another planetary body in the system much farther out.) Then came doubts. Another group of astronomers said that the observed variations might just be intrinsic variations in the star itself and not due to any planet. More observations suggested the worries were groundless. And on and on it went, in the tangled and confused way that real scientific discoveries are made.

William K. Hartmann



Unseen world: 51 Peg's planet

But hold on. Haven't there been false alarms and premature claims of extrasolar planets before? Why is this one so special? Or, as the title of our feature story on page 34 asks, "Is This Planet For Real?"

Actually, that title packs two questions into one. The first is basic: Does an object with planetary mass orbit the star 51 Pegasi? However, the second question is far more interesting, I think: What kind of planet *is* this?

So rather than just rehash the events surrounding the discovery, we thought it would be more interesting to take a look at what kind of thing it might be, this planetary child belonging to 51 Peg.

I hope you like the story. And if anyone asks you the Great Big Meaning of it all, I'd reply with the following: In a very small way, the known universe just got a bit heavier. But in an intellectual sense, it has become enormously larger and more exciting.

Sincerely,

Robert Burnham

Robert Burnham
Editor
rburnham@astronomy.com

LETTERS

Beginning in Style

I was astonished to read that ASTRONOMY would ever consider the Celestron GP-C102ED a "beginner's telescope" ("Test-driving Celestron's Apo Refractor," December 1995). I called three dealers who advertise in your magazine for quotes on this instrument. The average price quoted was $2,550, with the optional drive motor/ 1616controller package priced at an additional $450. I haven't yet met a beginner who has $3,000 to spend on an entry-level telescope. — *Roger J. Hoffman, MacLove Observatory, Beavercreek, Ohio, rhoff@gandalf.ball.com*

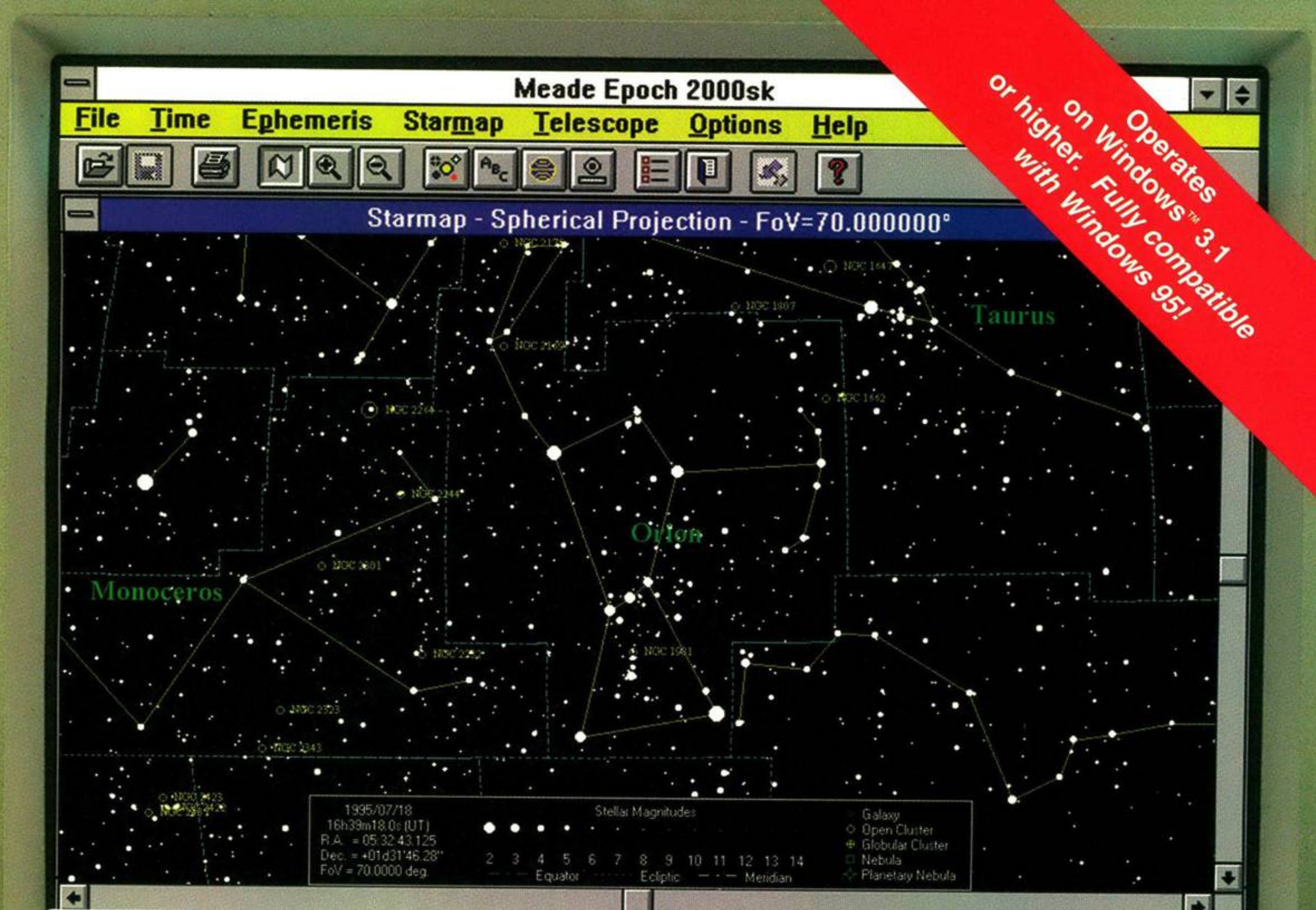
A Third Lurking in the Darkness?

After reading "Was Einstein Wrong?" (November 1995), I was fascinated by the discussion of how the binary system DI Herculis appears to disobey the principles of general relativity.

In the process of describing the mystery, astronomer Ed Guinan runs through a short list of possible explana-

[continued on page 16]

Operates on Windows™ 3.1 or higher. Fully compatible with Windows 95!


Meade Epoch 2000sk
File
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Telescope
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Taurus
Orion
Monoceros
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NGC 1647
NGC 1807
NGC 2169
NGC 1662
NGC 2264
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NGC 2301
NGC 1981
NGC 2232
NGC 2323
NGC 2343
NGC 2423
Stellar Magnitudes
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Open Cluster
Globular Cluster
Nebula
Planetary Nebula

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Epoch 2000sk *(above)* displays stars, planets, asteroids, and comets accurate in position to an *arc-second* level, the most precise position display of any sky software yet developed.

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The most powerful astronomical software ever made available can now be yours for only $149!

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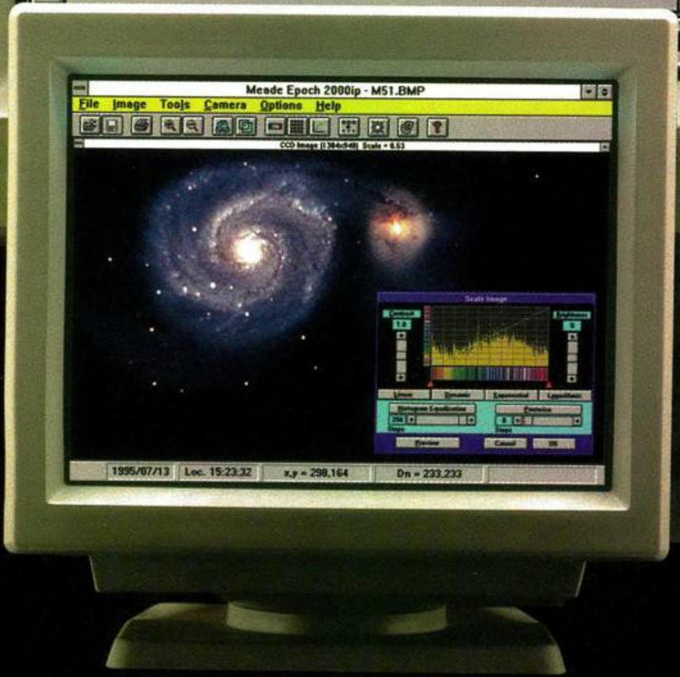
LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk . . **25**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Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$87.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**109.95** (3.79)
56mm (52°; 2")		**229.95** (5.48)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

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Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. **Internal batteries included.** Multi-coated optics. Bullseye reticle. 1.25"

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Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

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Series 4000™ Ultra Wide Angle 84°

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)–**4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (5.48)

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Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; 1.25": $29.95 (2.98)

Variable-Projection Camera Adapter (1.25")

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For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

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Complete with tripod and 2 eyepieces.

Includes the same equatorial mount of larger Meade models at right. Dual-axis worm-gear slow-motion controls permit easy tracking of astronomical objects. Two eyepieces (1.25") for powers of 36X and 100X. Multi-coated objective lens resolves to the theoretical limit.

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Meade Model 4500 4.5" f/8 Equatorial Reflector

World's largest-selling 4.5" telescope!

The finest first-telescope available. *Provides stunning optical performance on the Moon, planets, and hundreds of deep-space objects.* Precision equatorial mount includes worm-gear slow-motion controls in RA and Dec and full-length (50") aluminum tripod. 6 x 30 finder, rack-and-pinion focuser (1.25"), multi-coated MA 25mm eyepiece (1.25"). *Immediate delivery through your authorized Meade dealer.*

Fully automatic tracking with #531 Motor Drive *(below)*

$399 (22.40)

Meade Model 390 90mm f/11 Altazimuth Refractor

Perfect for land-viewing or astronomy.

Excellent imaging power for any terrestrial application, or for observing hundreds of astronomical objects in sharp detail. Smooth dual-axis controls; multi-coated optics. Supplied with 6 x 30 finder, MA25mm eyepiece (1.25"), aluminum tripod.

Includes flexible steel cable controls on both axes.

$499 (23.60)

Meade Model 395 90mm f/11 Equatorial Refractor

Multi-coated, high-resolution optics.

Includes flexible steel cable controls on both axes.

Accepts #531 Motor Drive *(below)*

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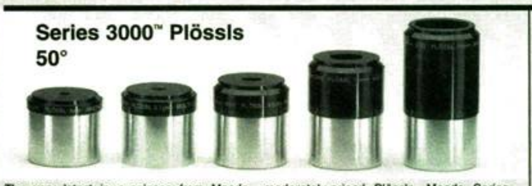
#531 Motor Drive

Attaches in seconds to the equatorial mounts of Meade Models 285, 4500 or 395 telescopes. Permits fully automatic tracking of celestial objects. Cordless operation anywhere in the world from 3 (user-supplied) AA batteries. **$99.50** (4.78)

Series 3000™ Plössls 50°



The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 3000™ Plössl 40mm 44°

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.** each: **$37.95** (2.98)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25". **$59.95** (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, at right. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.45)

HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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FREE! $800 CCD Equipment System!

Now, for a limited time, when you purchase a Meade Pictor 416 or 1616 CCD imager at the regular price, **we'll include an $800 Meade CCD Equipment System—everything you need for advanced CCD imaging—absolutely FREE!** Purchased separately, the CCD Equipment System is priced at $807 and includes these important products:

Meade Pictor 201 Autoguider: Allows completely automatic guiding of your Pictor camera during CCD imaging or your 35mm camera during long-exposure astrophotography.	**$395.**
Meade CCD Off-Axis Guider System: Complete with adapters for 1.25" eyepiece holders and for Schmidt-Cassegrain rear-cell threads. Use with the Pictor 201 on guide stars to 10th-magnitude.	**119.**
Meade CCD Image-Orientation Adapter: Threads into the Off-Axis Guider and permits precise image orientation on the CCD chip.	**35.**
Meade Epoch 2000ip Image Processing Software: Professional Windows-based image processing that permits the enhancement and analysis of CCD images using the most advanced techniques, including dynamic scaling, histogram equalization, image convolution, unsharp masking, median filtering, RGB merging, and more.	**199.**
Meade Foam-Lined Carrying Case (19" x 14" x 7"): Provides for secure storage and transport of your Pictor 416 or 1616 CCD imager as well as all items of the CCD Equipment System described above.	**59.**
Total price of all items if purchased separately:	**$807.**

The Meade Pictor 416 CCD Imaging Camera is packed, at no additional charge, with the **Meade $800 CCD Equipment System** during the period of this special offer.

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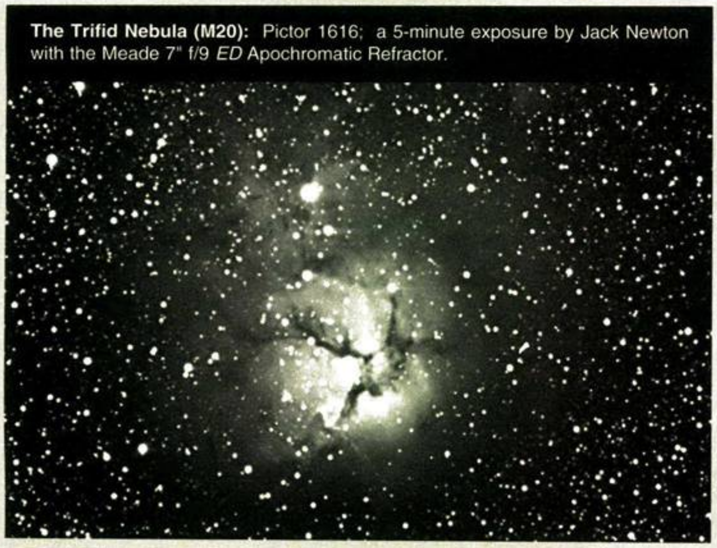
The Trifid Nebula (M20): Pictor 1616; a 5-minute exposure by Jack Newton with the Meade 7" f/9 *ED* Apochromatic Refractor.



Pictor 201 Autoguider: For flawless, ultraprecise autoguiding during long-exposure astrophotography or CCD imaging. Automatically locks on to guide stars as faint as 10th-magnitude and makes all required dual-axis corrections. Results in perfectly guided astrophotographs or CCD images during even the longest of exposures. Completely self-contained; no host PC required. **$395.** + $10 packing & shipping in 48 states.

Pictor 208 Autoguider/Imager: For an amazingly low price, the 208 gives impressive imaging capability even to the novice. On telescopes of 4" aperture and larger, the Pictor 208 yields very satisfying results and, in addition, is a full-capability autoguider, containing the exact same autoguider hardware and software as the Pictor 201, above. The 208 incorporates the Texas Instruments TC-255 microchip, by far the largest, highest-resolution chip available in any CCD unit in its price range. **$795.** + $15 P & S

Pictor 216 CCD Autoguider/Imager: Identical in operation and size to the 208, the Pictor 216 includes a 16-bit A/D converter for 65,536 brightness levels. The result is a level of image quality only obtainable on competing units that sell for almost twice the 216's price. Combining high-resolution imaging with low dark current, the Pictor 216 satisfies the long-term CCD imaging requirements of the majority of serious amateurs. **$1295.** + $15 P & S

Pictor 416 CCD Autoguider/Imager: Armed with the powerful Kodak KAF-0400 CCD microchip, the Pictor 416 is the most advanced high-resolution CCD system available under $5000. And, with its standard-equipment SCSI interface, the 416 can full-frame download in *one second!* The Pictor 416 is a powerful CCD system on any telescope; attached to a Meade LX200, its capabilities are truly awesome. The auto-mosaic feature, for example, permits the imaging of an arbitrarily large sky area **automatically** on user command. **$2495.** + $25 P & S

Pictor 1616 Autoguider/Imager: For professional-level applications the Pictor 1616 utilizes the Kodak KAF-1600 microchip, one of the largest (13.80 x 9.20mm) CCD chips in commercial production. Identical in pixel density and dark current to the 416, but with *four times* the chip area, the 1616 permits the imaging of very large sky areas: a sky area of 23' x 15' with an 8" f/10 Schmidt-Cassegrain, almost one-half the lunar surface in a single exposure. The 1616 is the finest CCD imaging system available at under-$10,000. **$6495.** + $40 P & S

The special Meade CCD Equipment System offer is effective beginning July 20, 1995, at participating Meade dealers in the U.S.A. and Canada. *This offer is valid until further notice and may be withdrawn at any time.* ■ All prices shown are suggested U.S. national mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable. ■ For safety reasons AC-powered personal computers should be used indoors only. ■ The Meade brochure ***CCD Imaging Made Simple*** is available free of charge, or send $3.00 for the 76-page **Meade *1995 General Catalog*.**

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ASTRONOMICS, Norman, OK, Orders: 800-422-7876; Information: 405-364-0858

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Orders & Information: 818-505-8424

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STARFINDER DOBSONIANS

Dobsonian telescopes with quality Meade® optics and components — at a fraction of the price you'd expect to pay.

16" f/4.5
$1095.
12" f/4.8
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10" f/4.5
$595.
8" f/6
$425.
6" f/8
$325.
STARFINDER
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All models shown with optional #637 6 x 30mm or #545 8 x 50mm viewfinders.

Compare *feature-for-feature* with other similarly priced Dobsonians!

- **Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass:** Unlike the plate glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians are made of Grade-A, fine-annealed Pyrex—the exact same professional-quality optics used on Meade Starfinder Equatorials.

- **Precision Components:** Including a full-size rack-and-pinion focuser (1.25") with 2.6" travel and fully-adjustable *4-vane* secondary mirror system.

- **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.

- **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right)*. All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.

- **Performance!** A Meade *Starfinder* Dobsonian or Equatorial opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

ACCESSORY OFFER!

At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

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Orders & Information: 818-505-8424.

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STARF
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Computerize your Meade® Starfinder™ Dobsonian or Equatorial for only $295!

Spend your time **observing, not searching** for objects! **With the incredible Meade Magellan™ Telescope Computer System** attached to your Meade Starfinder Dobsonian or Equatorial, finding any of **12,218 celestial objects** is almost as easy as pointing the telescope.

- Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!

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MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

- **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.

- **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds*. No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* ***plus*** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial
6", 8", or 10" . . . . $495.
#2019: for Starfinder Equatorial 16" . . . 595.

Prices plus $20 packing & shipping in the 48 states.

INDER
UTERS

■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

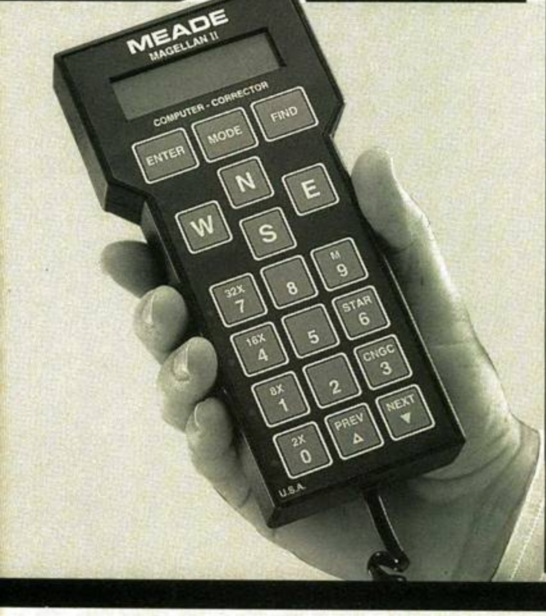
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

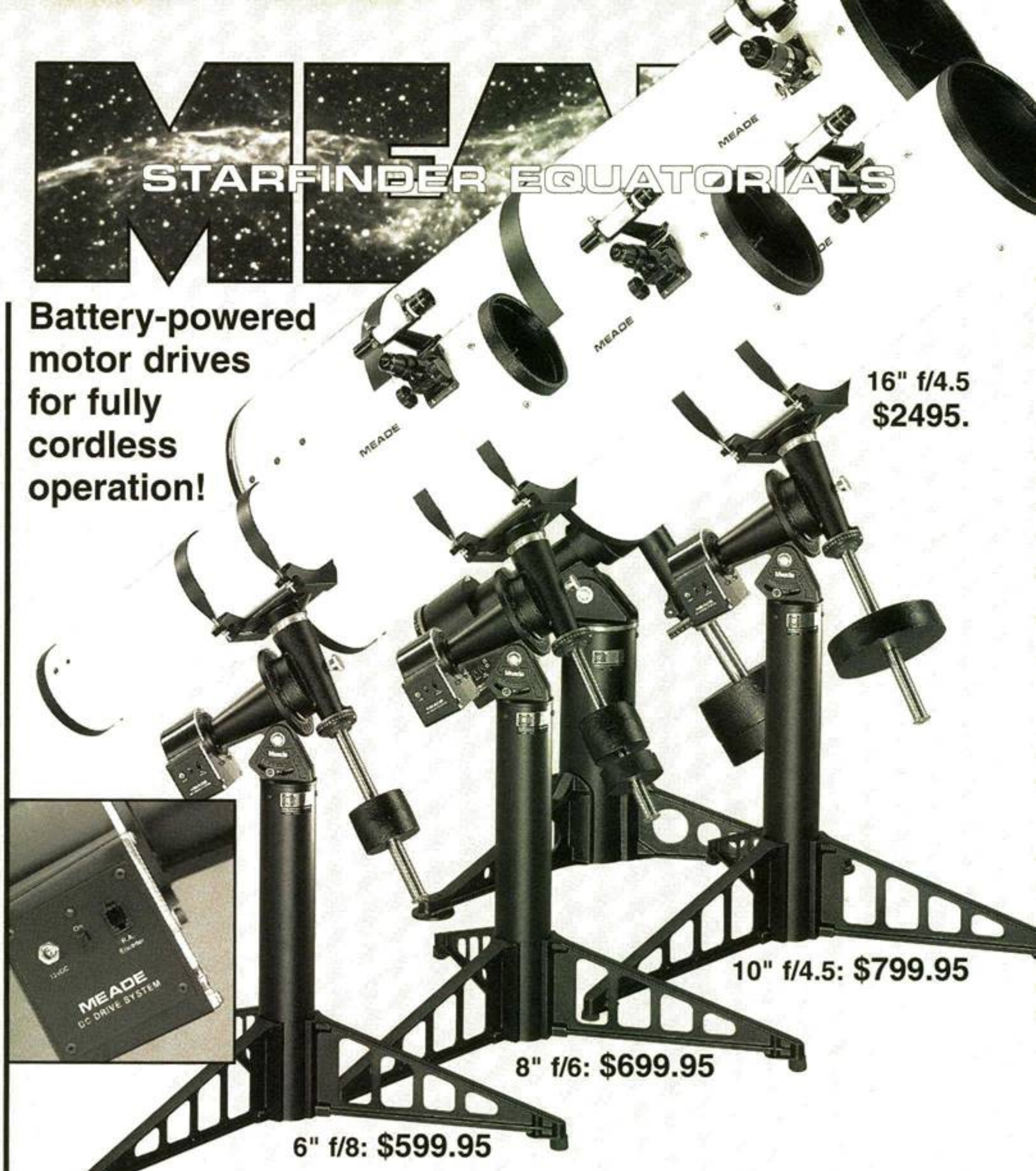
Meade Magellan I Telescope Computer Systems

#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" .... $295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" .... 295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16 .... 295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of **Meade Bulletin 2900.**



Battery-powered motor drives for fully cordless operation!



Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 4 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 4 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Meade 1995-96 General Catalog, $3.00 postpaid, is available from your authorized Meade dealer or directly from Meade Instruments.

ACCESSORY OFFER!

At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

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MEADE
MEADE 127ED/APO EMC
Meade LXD 650

Meade Model 127ED:
5" *ED* Apochromatic Refractor.
Shown with optional #1697 Computer Drive System.

Background image: **the Omega Nebula (M17) —**
A 5-minute image by Jack Newton using the Meade 7" *ED* Apochromatic Refractor and Meade Pictor 1616 CCD Imager.

ED APOCHROMATIC REFRACTORS

"This is the best black-and-white CCD image of M17 that I have ever taken with any telescope. I just couldn't believe that this could be done in a 5-minute shot with a CCD camera and a 7" refractor. I'm amazed at how the telescope performs, even against my own 25" Newtonian." **—Jack Newton**

Fortunate indeed is the observer with a Meade *ED* Apochromatic Refractor at his or her disposal, for these are professional-class instruments capable of serious research. Observe structural detail and color variations within Jupiter's Red Spot and at the boundaries of 8 to 10 cloud belts; resolve all three of Saturn's main rings and substructures within the rings themselves. *Simply put, if you're looking for the finest, textbook-perfect, ultra-high-resolution, high-contrast imaging of the skies that astronomical instrumentation, of any type, can provide, then a Meade ED Apochromatic Refractor is for you.*

Use the massive Meade **LXD 650** (4", 5") or **LXD 750** (6", 7") equatorial mounts in conjunction with the optional **#1697 Computer Drive System** to slew the telescope across the sky and computer-point the instrument, automatically, *to a precision of one arc-minute.* ***Meade LXD mounts are the only commercially-available German-type mounts capable of such a feat.*** Actuate any of 9 pushbutton-controlled drive speeds (from 2x photoguide to 8°/sec. fast-slew) on both axes, automatically, to locate and center any object directly from its input R.A. and Dec. Or use the onboard database for even faster object centering. Included with the #1697 CDS, the Meade **Smart Drive**™ assures the extremely low periodic error essential to research-level photographic or CCD imaging.

More than 40 Meade optional accessories are available to suit virtually any observing, photographic, or CCD imaging requirement.

Supplied complete per catalog specifications:

4" f/9 Model 102ED	**$2495.**
5" f/9 Model 127ED	**2995.**
6" f/9 Model 152ED	**4495.**
7" f/9 Model 178ED	**5495.**
#1697 Computer Drive System	**695.**

Packing and shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.

16" LX200

Professional instrumentation for the demanding school, college, or university research program—or as the ultimate personal telescope for the advanced amateur.

Professional-grade 16" f/10 optical system meets or exceeds advanced requirements; includes BK7 correcting plate for high UV transmission and EMC super multi-coatings. ■ **Massive one-piece fork mount** permits substantial auxiliary equipment to be piggybacked with rock-solid stability. ■ **Large 11" worm gears** on both axes, with factory-programmed Smart Drive™; periodic error less than 5 arc seconds. ■ **Automatic GO TO capability** to any object in the onboard 64,350-object database or to any input R.A. and Dec. ■ **High-Precision Pointing™** to within one arc-minute in the GO TO mode. ■ **DC servo drive systems** with integrated encoders and planetary gearboxes; encoder resolution: 0.13 arc secs. ■ **Six pushbutton-controlled drive-speed rates,** from photo-guide to fast-slew on both axes, simultaneously. ■ **Microprocessor controlled sidereal-rate tracking** in AZ or EQ modes with quartz accuracy. ■ **Home-Pulse Acquisition** permitting remote alignment and operation through a modem link to the telescope's RS-232 interface. ■ **Control panel connectors** for optional systems including CCD autoguiders and imagers, electric focuser, and the Meade **#1222 Field De-rotater** for long-exposure astrophotography in the AZ mode. ■ Available with **supergiant transportable field tripod** (2-person field set-up in less than 10 minutes); **permanent altazimuth pier** (permitting the entire instrument to be housed in a 2-meter dome); or **permanent equatorial pier** (in cases where piggybacked astrocameras do not permit field de-rotation).

The Meade 16" LX200 is in continuous production at the Meade Irvine, Calif. factory. **Delivery time:** 4 to 12 weeks. **Price:** $14,950, complete with supergiant field tripod, plus $385 packing and shipping in the 48 states; prices slightly higher with permanent altazimuth or equatorial pier.

For your copy of the all-new **1995 Meade General Catalog** ($3.00), write Meade Instruments or contact your authorized Meade Advanced Products Dealer.

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Meade Instruments is pleased to recommend the authorized Meade dealers on these pages for your telescope-buying requirements. Whether you're looking for a quality entry-level telescope at under-$200, a fully equipped professional instrument at over-$5000, or one of more than 2 dozen models in between, there's a Meade telescope that's right for your budget and applications.

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Over 100 stores nationwide.
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Woodland Hills, CA 91364
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Boot's Camera
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Fresno, CA 93710
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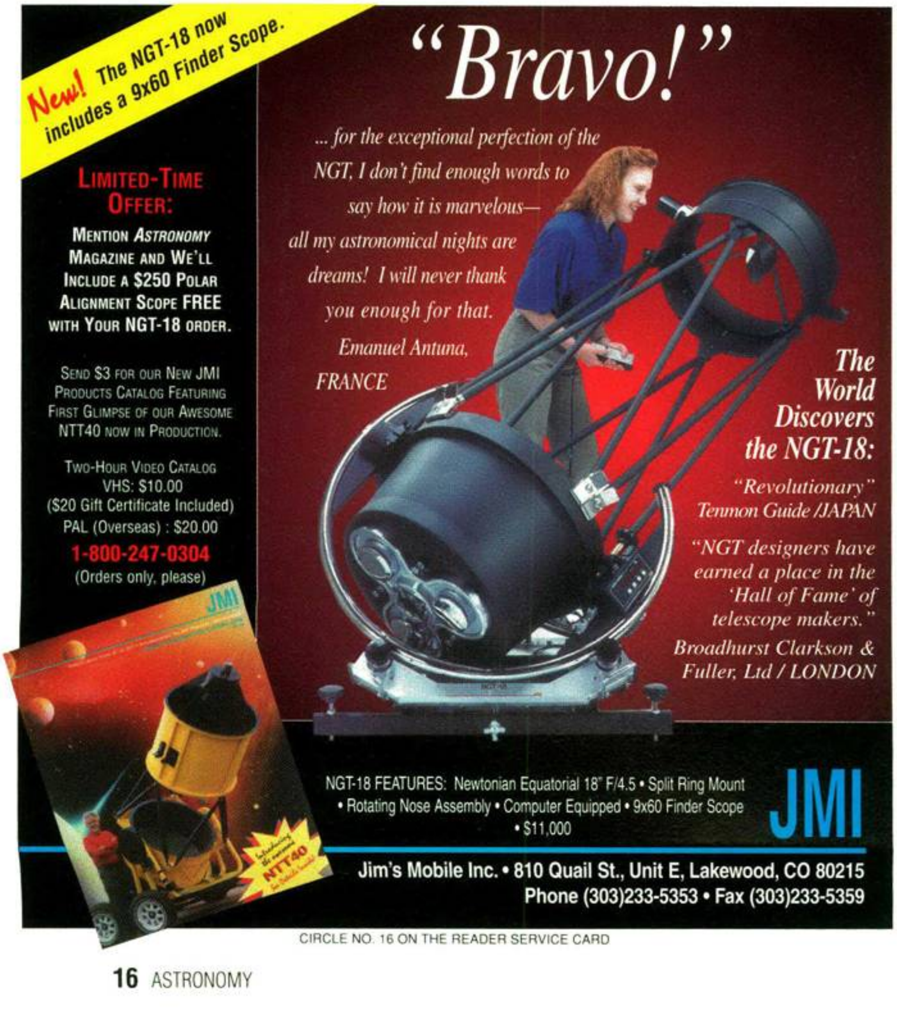

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LETTERS

tions for the binary's behavior. In most cases, he does an adequate job of discrediting the ideas. But what about the possibility of a third, unseen companion orbiting the system? Perhaps such a star is disturbing the relativistic rhythm of the binary's orbit.

Guinan says that in order for a third body to produce the observed effect and remain undetected, it would have to orbit nearly perpendicular to the plane of the binary's orbit and have a mass of between one-half and one solar mass. Given these conditions, Guinan concludes, that scenario is "highly unlikely."

But highly unlikely is not equivalent to impossible. When dealing with a sampling of something as immense as the universe, many seemingly highly unlikely situations can be found. The Milky Way is awash with binary star systems, the vast majority of which appear to conform to general relativity. That one or two should have an oddball third star involved is hardly an outrageous proposition. Is not tearing down general relativity even less probable, in the face of vast supporting evidence? — *Len Arends, Tehachapi, California*

— Len Arends raises a valid point. However, his statement that the vast majority of binary stars appears to conform to general relativity is inaccurate. As the article explained, DI Herculis and AS Camelopardalis belong to the mere handful of normal binary stars that can be used to check general relativity. In close binaries, Newtonian effects such as the tidal force overwhelm relativistic effects. In widely separated binaries, the relativistic effect is so small that it cannot be measured. The likelihood of a star orbiting DI Her or AS Cam in a highly inclined orbit is exceedingly improbable. To date, the binary pulsar is the only binary system that has been used successfully to test general relativity. In addition, Ed Guinan has used other methods not described in the article to preclude the existence of a third object in the DI Herculis system. — Robert Naeye.

Dust Off Those Books

C. Renee Beveridge has hit upon a rich subject in her Forum article (September 1995). I too have found it fascinating to read 19th-century astronomy books. This period doesn't receive the attention that the two periods of revolution that border it do.

As Beveridge points out, many things we take for granted were once important revelations. The spectroscope not only revealed the compositions of stars, but demonstrated that they are the sources of the same elements found on Earth. Eclipses of the Galilean moons showed that the speed of light is finite.

Some ideas in old tomes never made it. Thomas Dick, in Sidereal Heavens, suggested dropping constellations and employing a numerical system of organizing the stars. Some astronomers believed a planet existed between Mercury and the Sun, and that the Sun's great heat resulted from meteorites striking its surface.

Most used-book shops contain a few old astronomy works, offering a chance on cloudy evenings to dip into the past and explore the history of our hobby. — *David G. Russell, Candor, New York*

An Alien Clarification

In an otherwise generally favorable review, Robert Naeye states that 15 of 17 chapters in the first edition of *Extraterrestrials: Where Are They?* edited by Ben Zuckerman and Michael H. Hart (Pergamon Press, 1982) are "essentially repeated" in the new, second edition (Cambridge University Press, 1995). This accounting is incorrect. We have compared the two editions and find that only nine of 17 chapters are true repeats; three other chapters in the second edition are similar but differ significantly from corresponding chapters in the original. Perhaps Mr. Naeye compared only the titles of the chapters rather than their contents. So, even those people who have the first edition will find that about half of the 22 chapters in the second edition contain completely new material.

Why were some chapters not changed? For example, Professor Freeman Dyson, writing on "Interstellar Propulsion Systems," told the editors that he believes that his original discussion still conveys his opinion of this topic accurately. This is not an area in which rapid progress is occurring! Nonetheless, to add a new slant to the second edition we included a long chapter on "Interstellar Travel: A Review" by Ian Crawford, whose viewpoint differs significantly from that of Dyson. — *Ben Zuckerman and Michael Hart, Los Angeles, California* ☐

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ASTRO FORUM

It Was Just Plain Dark and Stormy

by Allie P. Katz

Anticipation had run high for two weeks prior to our departure. We just knew clear and dark (unbelievably dark) skies awaited us in Arizona. An astronomer's dream come true.

We had anxiously watched the weather reports for any and all signs of clearing. The past month had been an almost constant deluge of rain, sleet, hail, and more rain.

Two nights before Memorial Day weekend and the forecasts promised clearing — Arizona looked cloudless and spectacular! Hardly believing our good fortune, we loaded two vehicles with camping gear, food, a computer, one small gray dog, sky charts, logs, eyepieces, and telescopes. But not just any telescopes. Two trailers carried a 13.1-inch, 14.5-inch, 30-inch, and 36-inch telescope. We were going to see God on this trip!

Our spirits soared even as we jolted to a stop for the "parking lot" on Interstate 25 as we and everyone else in Denver headed south for the weekend. Even so, we muddled through the traffic and found clear sailing all the way to our weekend haven.

Moon River lay beautiful and steaming as it shimmered under wonderfully clear skies just past dawn. We couldn't have asked for a more outstanding site.

We napped after a 14.5-hour drive, gearing up for the long night ahead. Upon waking, it would be time to start preparing for the incredible skies we anticipated.

After a couple of hours of fitful, excited sleep, Starbuck and I cleaned our mirrors; with mine being half the size, I was finished long before he was. Enough time for a bit of meditation. As I came to, Starbuck broke the news that his mirror was flawed. After the cleaning, his 30-inch mirror had a nasty, non-removable film coating the entire surface, reducing the efficiency to something close to a 25-inch. Hmmm, not a good bit of news, but the mirror could be recoated. Not a complete loss. Things could be worse.

The Views Brothers awoke somewhat later. A few puffy clouds floated by, nothing to be worried about — this site always clears by nightfall.

"Look!" I pointed to the distinct and beautiful halo around the Sun. "Cool, huh?"

The Views Brothers looked at each other. Elwood ran for his weather charts.

"This condition is caused by hexagonal ice crystals in the atmosphere. It's a condition that, if accompanied by winds from the northeast, means rain within 14 to 24 hours."

Newton Views asked, "You mean like the wind we've got now?"

Undaunted, we all quipped, "It'll clear!"

Humming our individual telescope set-up songs, we placed our prized instruments strategically around the site. Occasional looks at the sky revealed more clouds, some not quite so puffy, and a high thin haze. Back to the weather charts.

"OK, we're now also dealing with cumulus fractus. If accompanied by winds from the northeast, it means rain within 14 to 24 hours."

"Okay, not to fear, it'll clear!"

Telescopes had been set up; it was time for collimating and alignment.

A look at my favorite eyepiece, a 25mm Clavé, revealed flakes of something that definitely had to go. I got out my trusty blow-brush and attempted to get the dirt out. Darn. I was going to have to take it apart. I unscrewed the bottom and failed to get to the flakes. I unscrewed the top part of the eyepiece and, yes, there they were. A little blow from the brush, but to no avail. They were really stuck. Luckily, Elwood had compressed air. I walked toward him, tapping my beloved eyepiece, and asked to use his air. Being the sharing type, he agreed, while I continued to tap and shake my eyepiece.

In slow motion, the elements flew out of the eyepiece tube and landed in the rather deep, fine, dark dust at Elwood's feet. I can still see the beautiful glass as it bounced, sunlight glinting off the edges.

Expletives. We scrambled to retrieve the elements and got everything. After I carefully cleaned the glass, Starbuck put the eyepiece back together. Phew!

I laid it gently on Newton's table, breathing a sigh of relief as I slapped my Telrad into the dust. More expletives. The group gaped at me. I rolled my eyes. Okay, I better get some sleep.

But first, let's check out the position of Comet d'Arrest. Newton and I gathered around Elwood as he brought up TheSky™ on his laptop computer. Thirty or so minutes later we were confident that we were easily going to feast upon a comet tonight.

While I slept, the Views Brothers and Starbuck planned their observing sessions. Upon waking, I was introduced to the observing accoutrements that the Views Brothers use, the volumes of obscure objects they have located, and the obscure objects they were planning to locate. I was way out of my league.

I look skyward. For a brief moment I thought, "so what if it rains," but only for a moment. Who cares, I'm not a complete idiot at the eyepiece.

We all looked skyward. More clouds, high and low.

"Hmmm. Not to fear, it'll clear."

A thin haze hung in the air as the sky went dark, but we could see a moonless and bandless Jupiter. Enough stars to set computers by. M13 was tough, but not bad. Elwood spoke into his recorder, beginning to log the evening. We rated the sky a 1.5 on a scale of 0 to 10.

Thank heavens for the company we shared. Elwood's constant singing and joking to Newton's straight man kept us laughing all the time. I actually pulled a back muscle when Elwood explained why some animals look like they have two faces — one face on their face and the other on their behind. You know, like baboons. He was actually referring to my rather shaggy gray dog, Isis, who did her best to be perky in spite of being the butt of most jokes.

As the night sky deteriorated, we thought it best to catch a few hours' sleep as we waited for the clouds to move on, say to New Mexico.

"Wake us when the sky clears, okay?"

I agreed, but found that was not an easy task as, lo and behold, the stars managed to find their way out of the clouds. Definitely not a 10, but it could pass for a 6 or 7. Better than nothing, I thought, as I tried in vain to rouse my companions from their deep sleep.

Unfortunately, those were the last stars worth mentioning for the remainder of the trip.

The next morning dawned blue and beautiful, briefly. And when the weather broke, all hell cut loose.

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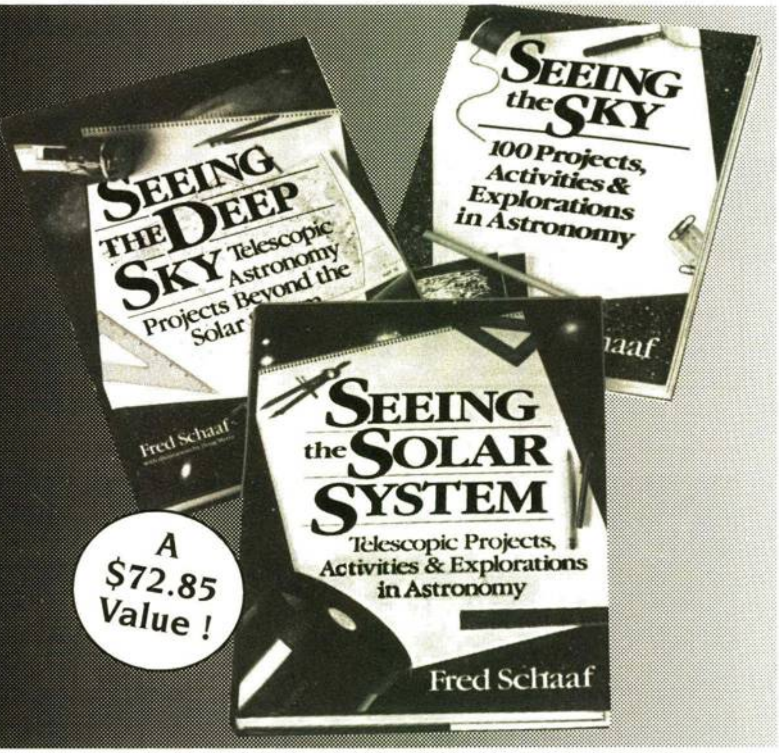
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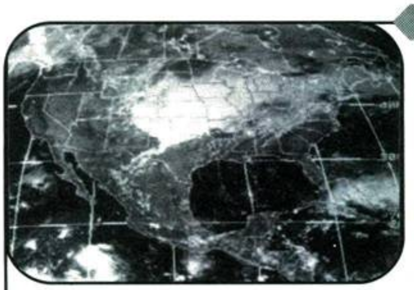

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dumped rain, hail, and more rain! Telescopes were practically thrown into the backs of trailers. Elwood literally threw himself and a tarp over the base of his 36-inch, as if that act itself was going to stop the hosing of any and all things not inside a bomb shelter. I vaguely remember someone yelling, "Sacrifice the smallest telescope to the weather gods." "Okay, sacrifice the dog."

Fortunately, the dog was hiding under a blanket, shivering and muddy, whimpering with each roll of thunder.

The rain stopped briefly just as we finished loading the trailers and were pondering our next move. To go south would add several hours to our already lengthy time in getting home. Let's try north, we agreed. A stop in town and Elwood checked with another Views Brother back home. His mission — to check satellites and weather forecasts. We would wait. Looking like a suspicious group of half-drowned vagrants, we sat on a street corner by a pay phone, waiting for the news.

When it came, it wasn't good.

"The weather is breaking up pretty much everywhere. You might get lucky about four hours south. Do not, whatever you do, go north."

The decision to head home came simultaneously with the next onslaught of rain.

The rain continued most of the drive through the rest of the day and long night as we steadily made our way through Arizona. A few hours' sleep at a rest stop recharged us for the last leg of our journey home.

We stopped for gas in a small town and thought breakfast would be nice. The gas station attendant was helpful.

"Just ahead down this street a few blocks, you can't miss the restaurant. Great for breakfast."

We drove through the pelting rain and pulled our vehicles into the small lakes they used for a parking lot. We ran toward the restaurant entrance and stopped, dead in our tracks.

With mouths gaping, hair dripping into our eyes, we stared in disbelief.

The large colorful sign over the entrance read — The Rainmaker Cafe.

Newton turned to Elwood.

"You get the gas, I'll get the torch."

We all nodded. "Hmmm. Not to fear, it'll clear." ☐

Allie P. Katz, also known as Patti A. Kurtz, hopes to write about better observing experiences in the future.

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ASTRO NEWS

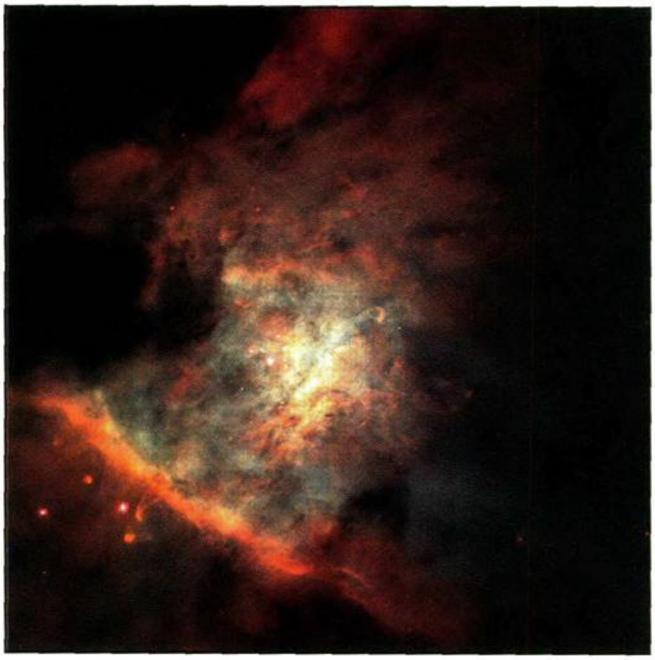
Solar Systems in the Making

A new composite image of the Orion Nebula's central region represents the latest installment in the Hubble Space Telescope "Greatest Hits" photo album. But it is more than just a pretty picture. By scrutinizing the image, C. Robert O'Dell of Rice University in Houston, Texas, and Mark McCaughrean of the Max-Planck-Institut für Astronomie in Germany, found evidence for disks of gas and dust surrounding 160 newborn stars. Based on the observed frequency, O'Dell and McCaughrean surmise that donut-shaped disks surround most young stars in the nebula.

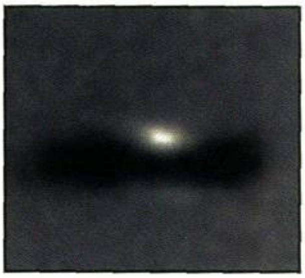
Astronomers think these disks are similar to the one that gave birth to the planets in our solar system. The minimum mass of each Orion disk is between one-third and 730 times the mass of Earth. This is not enough mass to form planetary systems such as our own, but O'Dell and McCaughrean think the disks are actually much more massive. "The building blocks to form planets are there, however that doesn't mean that planets will certainly form," cautions O'Dell.

Hubble images previously showed hints of disk-like structures in the nebula, but the new images of dark disk-shaped objects with young stars at their centers settle the matter once and for all. "What we're seeing for the first time are real images of proto-planetary disks around young stars," says McCaughrean.

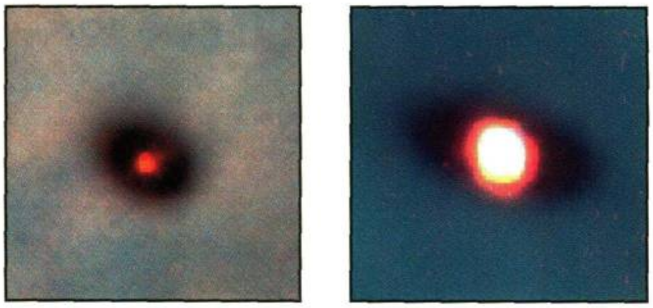
O'Dell and his graduate student Shui Kwan Wong assembled the mosaic from 15 different fields-of-view. The mosaic is 2.5 light-years across, but with the nebula's distance of 1,500 light-years, the photograph covers a patch of sky only 5 percent of the area of the Full Moon. Orion's four hottest stars, the Trapezium, lie near the center. The colors are very close to what people in the distant future will see if they can travel closer to the nebula. Blue represents ionized oxygen, green corresponds to hydrogen, and the red is nitrogen. Hubble's resolution reveals wispy tendrils as small as 4 billion miles across — roughly Pluto's distance from the Sun.


C. Robert O'Dell and Shui Kwan Wong (Rice University), and NASA

ORION MOSAIC. This composite image of the inner region of the Orion Nebula was assembled from 15 different fields-of-view. The photograph covers an area 2.5 light-years across.



AN EDGE-ON DISK 15 times the diameter of Pluto's orbit obscures its parent star. This is the largest disk seen in Orion. Astronomers think disks like this one are made up of 99 percent gas and 1 percent dust.

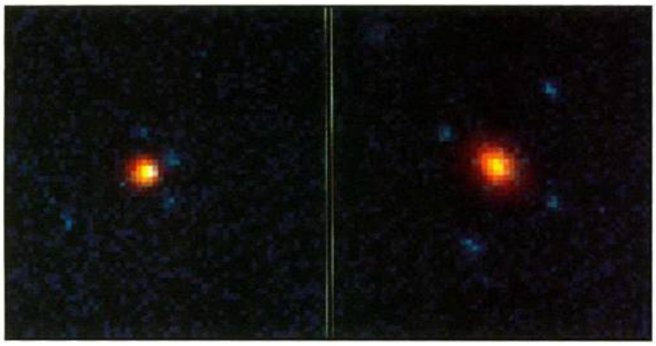

Mark McCaughrean, Max-Planck-Institut für Astronomie

PROTOPLANETARY DISKS surround young stars in the Orion Nebula. The disks themselves are roughly three (left) and six (right) times the diameter of Pluto's orbit. The bright central dots are newly formed stars, roughly 1 million years old.

Two New Cross-shaped Gravity Lenses

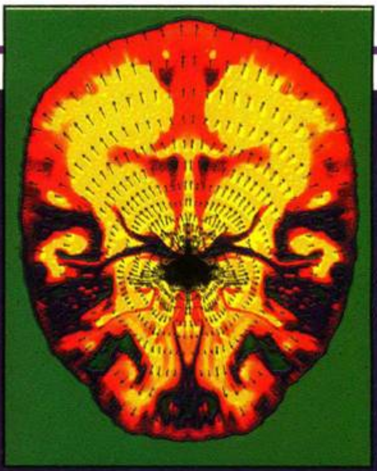
When Albert Einstein first computed in 1936 that the gravity of a massive object could deflect the light coming from a more distant object, he remarked that "there is no great chance of observing this phenomenon." Of course he had no way of knowing how much bigger and better telescopes would get. Many such gravity lenses have been found during the past 15 years.

Now a detailed survey of about 100 small pieces of sky conducted with the Hubble Space Telescope has turned up two "Einstein cross" gravitational lenses — objects whose light has been split into four separate images by the gravity of a



K. Ratnatunga (Johns Hopkins University) and NASA

FAINT BLUE CROSSES surround reddish elliptical galaxies in these images from Hubble's Wide Field and Planetary Camera 2. The gravity of each galaxy acts like a lens and bends the light from a more distant object, creating four separate images of it in the shape of a cross. The galaxies glow dimly at 22nd magnitude (right) and 24th magnitude (left) while the lensed objects glow at 26th and 27th magnitude, respectively.



Adam Burrows and John Hayes, Univ. of Arizona

A BRAIN SCAN of a Nobel prize-winning physicist? No, this is a two-dimensional Cray supercomputer simulation of a supernova explosion. The image, from Adam Burrows and John Hayes of the University of Arizona and Bruce Fryxell of NASA's Goddard Space Flight Center, shows how supernovae explode aspherically. The remnant neutron star is in the black area near the center. The thin blue shell represents a shock wave. Hot, buoyant blobs of material (the dark colors inside the shock wave) are pushing the shock wave outward into the stellar envelope (solid green), where it wreaks havoc and tears the star apart. Because most of the star's mass moves in one direction, the neutron star receives a high-velocity "kick" in the opposite direction. This explains why astronomers have seen neutron stars racing through the Galaxy at 900 kilometers per second. Movies of a simulated explosion can be accessed at the following Internet site: http://lepton.physics.arizona.edu:8000/movies.html.

closer galaxy. Kavan Ratnatunga and colleagues at Johns Hopkins University in Baltimore discovered the lenses, the first in which the lensing objects are relatively bright, though distant, elliptical galaxies with well-understood properties.

More than just astronomical curiosities, the new lenses could prove to be a significant tool for probing the universe. A detailed analysis of the images has already allowed the researchers to show that dark matter makes up more than 90 percent of the foreground elliptical galaxies.

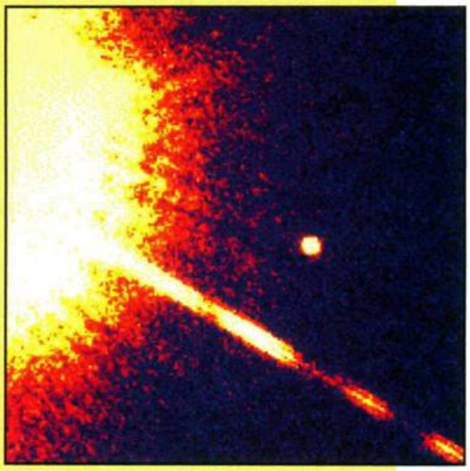
Observations of more such lenses and of their redshifts will also help astronomers estimate the density of matter in space. The answer to that question determines whether the universe will expand forever or eventually collapse. So far the total area surveyed equals about that of a Full Moon, so the whole sky should contain several hundred thousand such lenses, though the Hubble surveys are expected to find only about three per year.

Clementine Confirms Moon's Volcanic History

There's a reason why the "Man in the Moon" faces us. New research suggests that the dark basaltic flows on the Moon's nearside — the markings that seem to resemble a face — are due to the thinness of the crust there. In contrast, the lunar farside, which sports a thicker crust, is practically devoid of ancient lava flows.

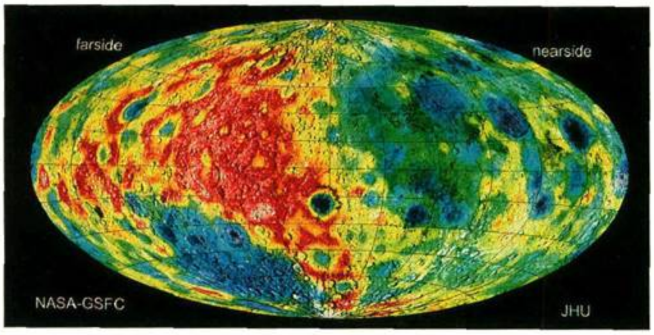
Scientists have long thought that the Moon's nearside experienced more volcanic activity because magma driven by pressure could reach the surface more easily through the relatively thin crust. A new study, based in part on crustal thickness data from the recent Clementine mission, confirms this theory.

Aileen Yingst and James Head of Brown University looked at basaltic deposits within the South Pole-Aitken and Orientale



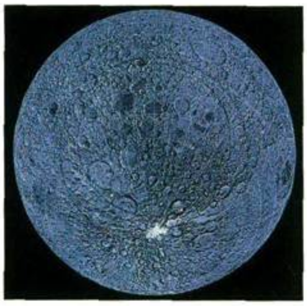
STScI

BINGO! The unassuming little dot near the center is a big deal for astronomers. It's the first definitive brown dwarf ever seen (see "The Best Brown Dwarf Yet," February 1996). Brown dwarfs are objects larger than planets but smaller than stars. The image, taken by the Hubble Space Telescope in November 1995, follows up on the discovery made by Shrinivas Kulkarni and his Caltech colleagues using a 60-inch telescope on Palomar Mountain. The brown dwarf is roughly 50 times Jupiter's mass, but its density is so great that its diameter is about the same as Jupiter's. The brown dwarf orbits the star Gliese 229 at about the same distance Pluto orbits the Sun. The system is about 19 light-years away in the constellation Lepus. Gliese 229 lies off the left edge of the image, but it is so bright that its light floods Hubble's camera.



Maria Zuber, Johns Hopkins University

THE VARYING THICKNESS of the Moon's crust (above) affects how much volcanic activity takes place on the surface. The thicker lunar farside (below) contains few marks of volcanism.



Aileen Yingst, Brown Univ.; mosaic image from Clementine mission

impact basins on the lunar farside. The researchers compared the amount of lava needed to form each of those ponds with the thickness of the underlying crust, as deduced from Clementine's maps of lunar topography and gravity. They found a direct link: The thinner the crust, the more lava had erupted. Areas of thickest crust had significantly fewer signs of volcanic activity.

The researchers suggest that magma is driven through the crust after pressure builds up in the reservoir of hot rock. Thus, magma underlying thin crust could burst through to the surface more quickly and easily than that in an area of thick crust.

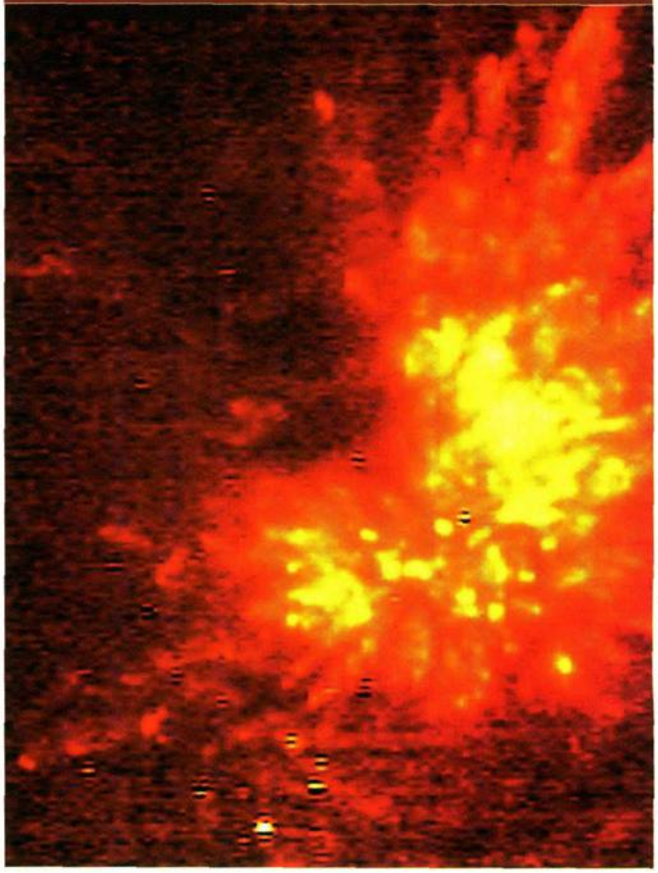
Yingst presented the team's results at the November meeting of the Geological Society of America in New Orleans, Louisiana.
— *Alexandra Witze*

Sun's Core Rotates Slowly

Just by watching spots on the Sun's surface, backyard astronomers can deduce that the Sun rotates more slowly at the poles than at the equator. About one-third of the way from the surface to the Sun's center the rotation becomes essentially uniform with a rate roughly equal to the equatorial value. Models of the Sun's interior indicate that this rate should persist all the way to the center.

But in studying their 1992-1994 data regarding waves on the Sun's surface, Yvonne Elsworth of the University of Birmingham in England and her colleagues found that the Sun's core apparently rotated more slowly than the surface. (See "Journey to the Heart of the Sun" in the January 1995 ASTRONOMY for an explanation of how surface waves reveal the nature of the Sun's interior.) They suspect that this was either a transient event or that the rotation rate changes with the Sun's activity cycle because previous studies by other astronomers do not indicate a slowing. In either case, present interior models cannot explain how the Sun could change its rotation in the core and will require substantial revision. The team presented their results in the August 24, 1995, issue of *Nature*.

"BULLETS" IN ORION appear in the upper right and lower left of this infrared image. The bullets are clumps of gas zooming through space at supersonic speeds. In the September 28, 1995, *Nature*, James Stone, Jianjun Xu, and Lee Mundy of the University of Maryland explain how these bullets form. The intense stellar wind from a massive young star sweeps up a dense shell of gas. The wind velocity later increases over several hundred years. The faster wind rams into the shell and accelerates it to high speeds, causing it to fragment into "bullets." The bullets race away from the scene, leaving shocked material in their wake. Stone's team notes that similar processes might occur in supernovae and planetary nebulae, where other supersonic bullets are seen.



Mark McCaughrean, Max-Planck-Institut für Astronomie

A Mirage in Space

One of the brightest light sources in the sky turns out to be not so brilliant. Astronomers thought FSC 10214+4728 was a newly formed galaxy or perhaps a luminous quasar located some 10 billion light-years from Earth. It was the most distant of the 300,000 objects observed by the Infrared Astronomical Satellite, implying that it must be

[continued on page 28]

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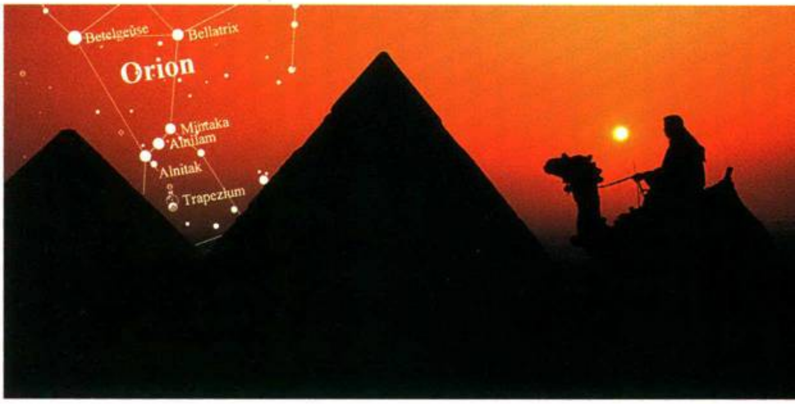

New theories have linked the positioning of Egypt's ancient pyramids with the celestial orientation of the three stars in Orion's belt. What discoveries await you in TheSky?

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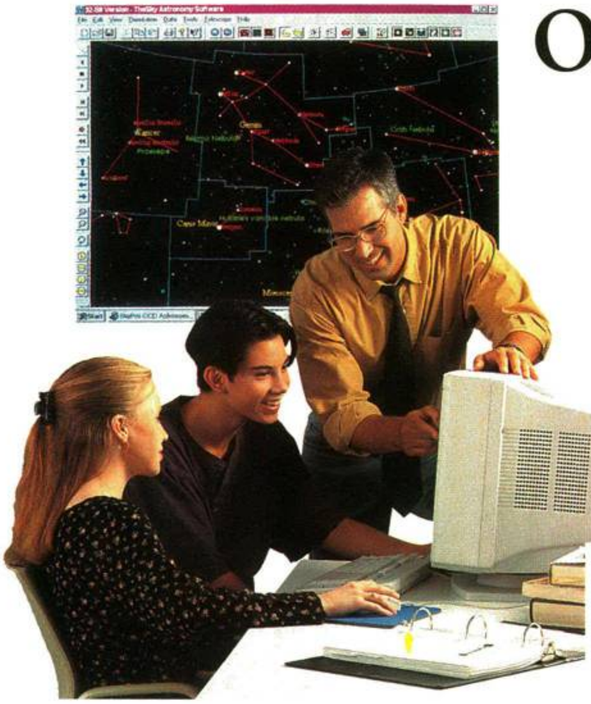

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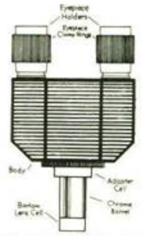

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The Subduction of Venus

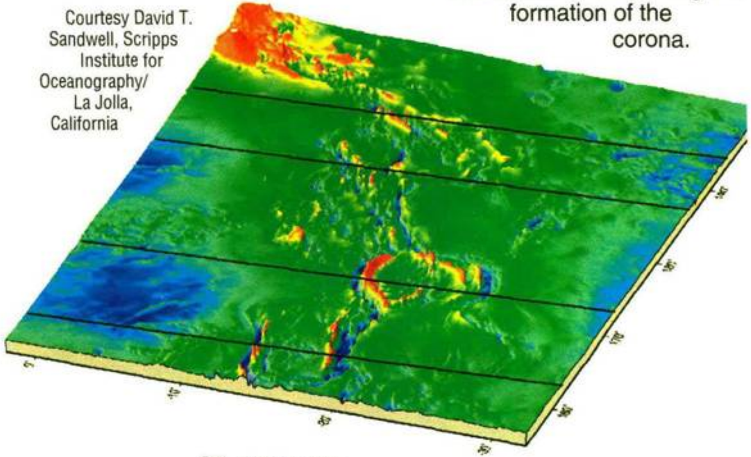
Geophysicists Gerald Schubert and David Sandwell have completed the first global survey of Venus for signs of subduction — the geologic process that continually recycles the Earth's surface and helps cool its interior.

Schubert, of the University of California in Los Angeles, and Sandwell, of the Scripps Institute of Oceanography in La Jolla, California, argue in the September 1995 issue of *Icarus* that subduction may also help Venus keep its interior cool.

The theory of plate tectonics holds that Earth's surface is covered by about a dozen rigid lithospheric plates that float on a layer of soft mantle rock. Oceanic plates dive beneath the continents at subduction zones, usually marked by deep ocean trenches. These relatively cool plates absorb heat from the mantle like an ice cube pushed down into a bowl of thick, hot stew.

Schubert and Sandwell searched the surface of Venus for geological structures similar to terrestrial subduction zones. In all, they found 10,000 kilometers of trenchlike structures on Venus. Occurring on Venus' surface near volcanic structures called coronae, the subduction zones may allow parts of the planet's dense lithosphere to sink into the deeper mantle and absorb some of its heat.

— *Daniel Pendick*



THIS IMAGE SHOWS the cracked surface of Venus near Latona Corona (round feature in foreground), a region where a vertical flow of hot mantle rock once caused the surface to bubble upward and crack nearby areas of the lithosphere. This may have initiated a process similar to terrestrial subduction, in which portions of Venus' rigid outer shell sink into the planet's interior along the cracks introduced during the formation of the corona.

Courtesy David T. Sandwell, Scripps Institute for Oceanography/ La Jolla, California

EVENT HORIZON

Goodnight Forever Pioneer 11

Pioneer 11, the stalwart little spacecraft that skimmed within 26,000 miles of Jupiter's cloud tops in December 1974, and then went on to make the first spacecraft flyby of Saturn five years later, sent its final signal home September 30, 1995. Now more than 4 billion miles from Earth, the spacecraft's power is too low to continue operating its instruments and transmitting data. At that distance, signals from Pioneer 11 take over six hours to reach Earth. The spacecraft, which carries an engraved gold plaque bearing a message from Earth to other civilizations it may encounter, will continue its outward-bound journey to the stars unimpeded. Next stop: the Lambda Aquilae star system. Arrival date: 40,000 centuries hence.

Conehead Rocket Passes Muster

NASA

What looks like a runaway church steeple in the photo at right is really the test flight of an unpiloted rocket called the Delta Clipper-Experimental (DC-X). NASA hopes that the vehicle eventually will reduce launch costs by lofting payloads into space via a single stage. The DC-X was successfully tested at White Sands Missile Range in New Mexico last summer and will be used later by NASA in their Reusable Launch Vehicle technology program.

The Most Distant Supernova

The most distant supernova — indeed, the most distant star — ever seen was discovered last March in an extremely distant galaxy by scientists using the 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. Based on the star's redshift and its brightness, astronomers estimate it lies 6 billion light-years away. The discovery will contribute to astronomers' efforts to better determine cosmological distances.

The Heaviest Star

Astronomers observing with the Hopkins Ultraviolet Telescope have observed a star whose outer layers are rushing outward at speeds of up to 2,300 miles per second. The reason for this high-velocity outflow is due to the star's incredible energy output. Analysis of earlier data from the Hubble Space Telescope and the European Southern Observatory indicates this star may be 190 times as massive as the Sun, the largest value to date.

A Martian Ring System?

Dust particles knocked off the Martian moons Deimos and Phobos may go into separate orbits around the planet, lingering there to form quasi-permanent rings. According to Douglas Hamilton of the University of Maryland, observations from Earth or spacecraft in Martian orbit may be able to detect them in the next five to ten years.

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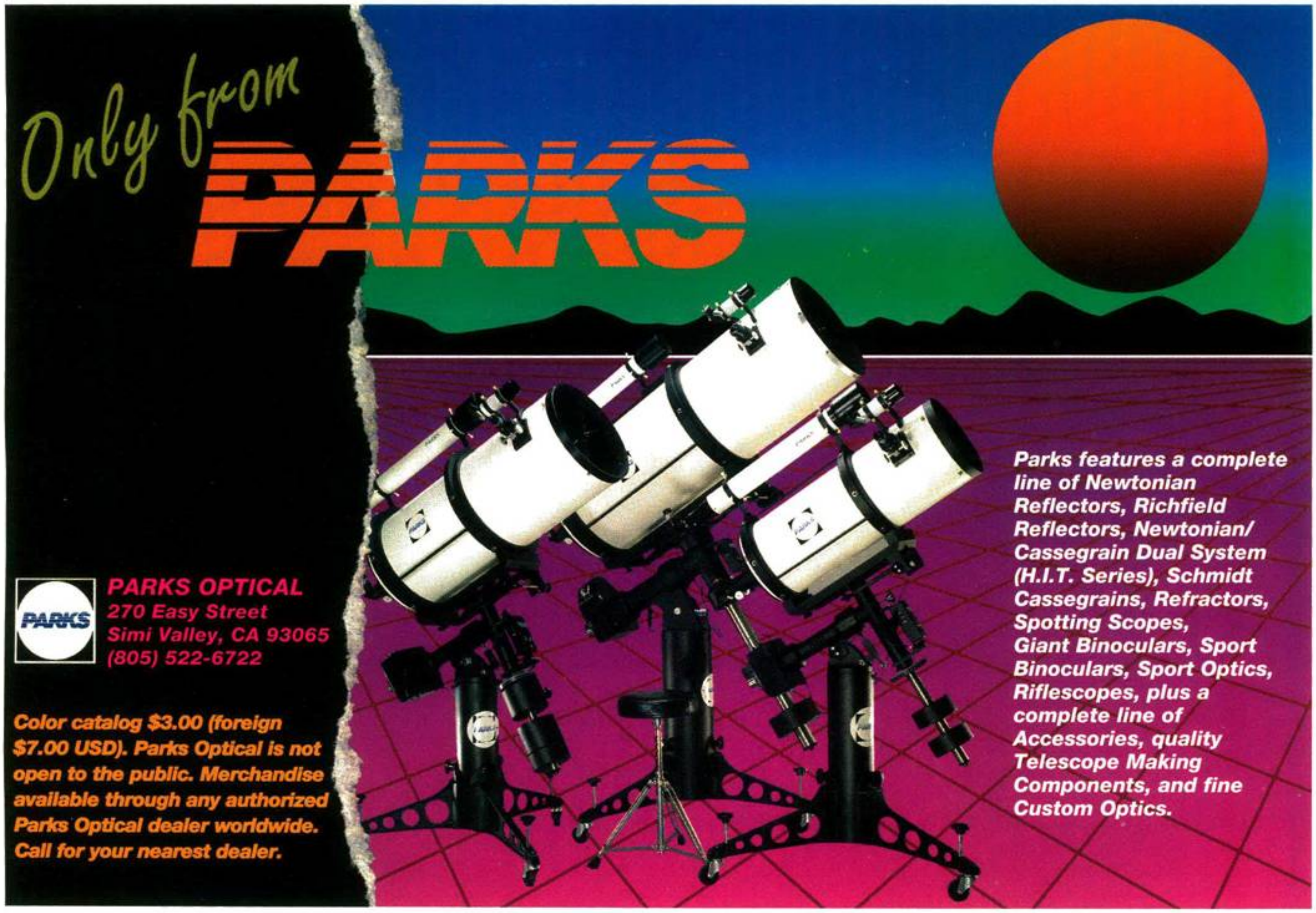

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USPers Get the 'Ultimate' Experience

The time around October's New Moon holds special meaning for someone headed to the Ultimate Star Party. It means getting together under some of this country's darkest skies outside of Fort Davis, Texas, for some serious deep-sky observing. USP '95 was no exception: It treated 30-plus people to eight straight nights of clear skies during the last full week of October.

The excitement kicked off on Friday evening, October 20, after twilight ended and optical collimations were completed. Unfortunately for big Dob owners, the nylon shrouds that covered their telescopes' trusses caught the night's blustery winds like sails. This pivoted scopes around at rather unpredictable times like oversized windsocks. Although Texas-style breezes stuck around the entire week, people still managed some great observing.

Most evenings began with views of lovely Comet Schwassmann-Wachmann 3, a real sleeper during the autumn of 1995. Its wispy tail stretched 1° to 2°. Not far away was Saturn, which looked bold and beautiful through an 18-inch telescope built by Peter Smitka, who made the 28-hour journey to USP '95 from Wisconsin. Each night, everyone queued up at Smitka's scope to glimpse a shifting array of moons near Saturn's edge-on rings.

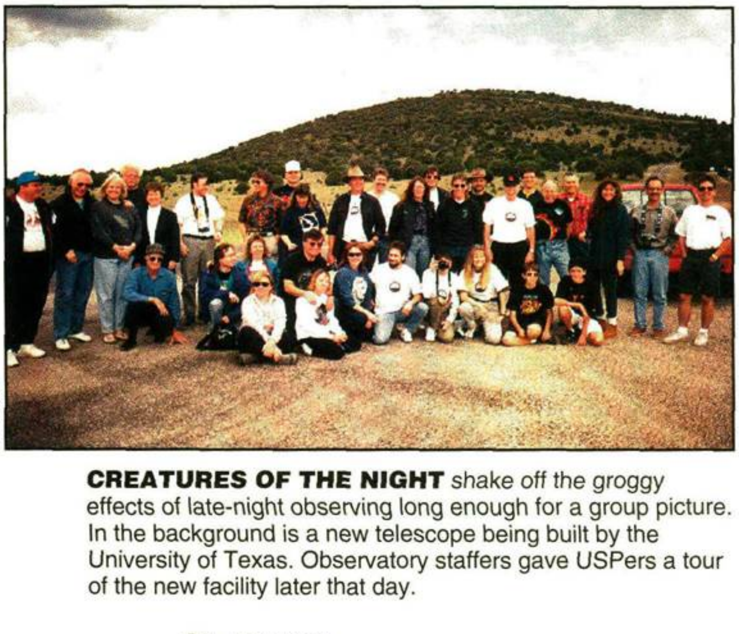
California observers Sheryl Johnson and Debbie Searle treated fellow observers to a fabulous galaxy cluster in Fornax through their 20-inch Dobsonians. This fun-loving duo also brought along lively recorded music for some toe-tapping entertainment during the late-night hours.

Accomplished astrophotographers Tony and Daphne Hallas left imaging behind in California to observe through a unique 25-inch f/4 Dobsonian mounted on an equatorial platform. Along with other delights, the Hallas' dazzled USPers with a spectacular view of the Eskimo Nebula in Gemini. The planetary's inner ring encircled a dark zone where the Eskimo's face stood out as plain as day.

While all this sightseeing was going on, Colorado observer Bob Ross remained bathed in the pale red light of his computer monitor. Ross diligently logged his observations between coaxing his 36-inch f/5 into obedience, although the winds clearly wanted their way with it. Braving capricious gusts from atop a 12-foot ladder, he busied himself by drawing seven comets, sketching the fields of 20 double stars, and observing more than 300 obscure targets in his quest to glimpse every deep-sky object listed in *Uranometria 2000.0*.

Another 36-inch owner, Larry Mitchell of Houston, Texas, was content to give the party its best view of the Ring Nebula in Lyra. The planetary's central star was easily seen and occasionally a second central star popped into view. Mitchell's laid-back sense of humor was put to the test after one particularly strong gust of wind blew a 12-foot ladder onto his Lincoln Continental. He considered turning the car around so it might acquire a matching dent on the other side.

Week's end saw even the most die-hard observers hoping for a dash of cloudy weather, if only for a night's restful respite. But it never happened; right through Saturday, October 28, clear weather prevailed. Weary but elated USPers packed up the next day, cheerfully sprinkling their good-byes with the refrain, "See you at USP '96!" — *Patti Kurtz*



CREATURES OF THE NIGHT *shake off the groggy* effects of late-night observing long enough for a group picture. In the background is a new telescope being built by the University of Texas. Observatory staffers gave USPers a tour of the new facility later that day.

Patti Kurtz

Kenneth Glyn Jones, Webb Society Founder, Dies

British deep-sky observer and author Kenneth Glyn Jones died from heart problems on July 26, 1995, at the age of 79. In 1968, Jones helped form the Webb Society and served as its first president for 23 years. The Society fosters deep-sky observing all over the world.

Jones' interests were many and varied. As a skilled instrument maker he built an eclipse predictor and a grandfather clock that shows the lunar phases. His interest in history led him to write a nine-part series for the British Astronomical Association called The Search for the Nebulae, which later came out as a small book.

A much bigger undertaking was the well-known book *Messier's Nebulae and Clusters*, published in 1968. The project saw him observe each object from England with a homemade 8.5-inch Newtonian reflector. Jones even made a trip to South Africa to better glean more southerly objects. The first edition of the book was a collector's item before he was asked by Cambridge University Press to revise and republish it in 1991.

Jones also edited all the handbooks which the Society produced between 1979 and 1990. Editorials in the Society's *Quarterly Journal* reflected his breadth of knowledge of not just astronomy but also philosophy and history. Even after he retired as president at the age of 75, he continued to take a keen interest in the Society and was a major contributor to the 100th *Quarterly Journal* published in April 1995.
— *Robert W. Argyle*

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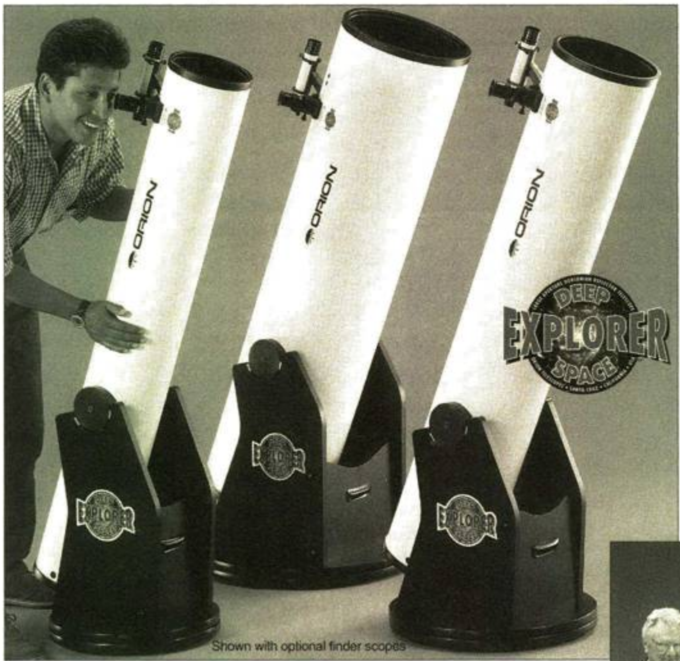

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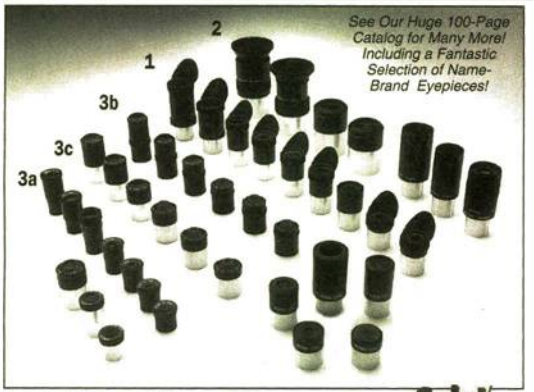

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Is This Planet for Real?

Astronomers have found the first planet orbiting another solar-type star. But they still don't know what the planet is like or what its discovery means.

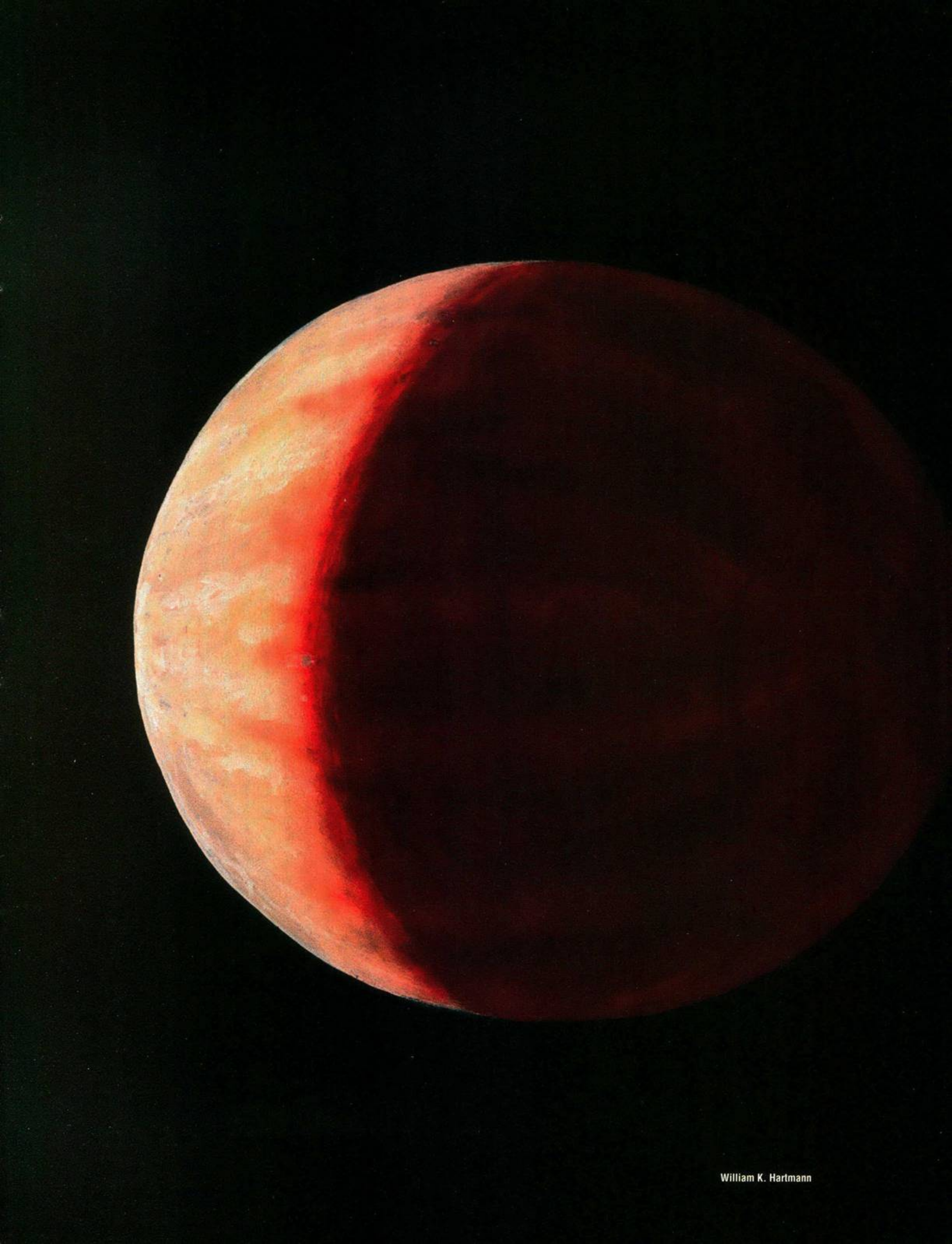
by Robert Naeye

On October 6, 1995, Michel Mayor of the Geneva Observatory stepped up to the podium in a small conference room in Florence, Italy. What Mayor had to say stunned the assembled gathering of astronomers. He and colleague Didier Queloz had discovered what many astronomers had spent decades searching for to no avail: the first planet orbiting another Sun-like star.

Mayor and Queloz had found a planet with one-half to two times the mass of Jupiter orbiting very close to the star 51 Pegasi, a fraternal twin of the Sun located 55 to 60 light-years from Earth. Ten days later, Geoff Marcy of San Francisco State University and Paul Butler of the University of California at Berkeley confirmed the discovery. By November, all competing explanations, such as stellar pulsations, had been virtually ruled out. Unless 51 Pegasi is pulling off a masterful con job, this planet is for real.

The discovery has galvanized those who search for extrasolar planets. Astronomers want to know how many stars are accompanied by planets and how these planets are arranged, because this will tell them how planetary systems form and evolve. But in the back of their minds is the deeper underlying issue of life in the universe. Because life as we know it can only exist on planets, the prevalence of planets will go a long way towards addressing the mystery of whether or not we are alone.

The unusual nature of 51 Pegasi's planet, however, raises questions as to whether it really is a planet in the conventional sense. "As far as



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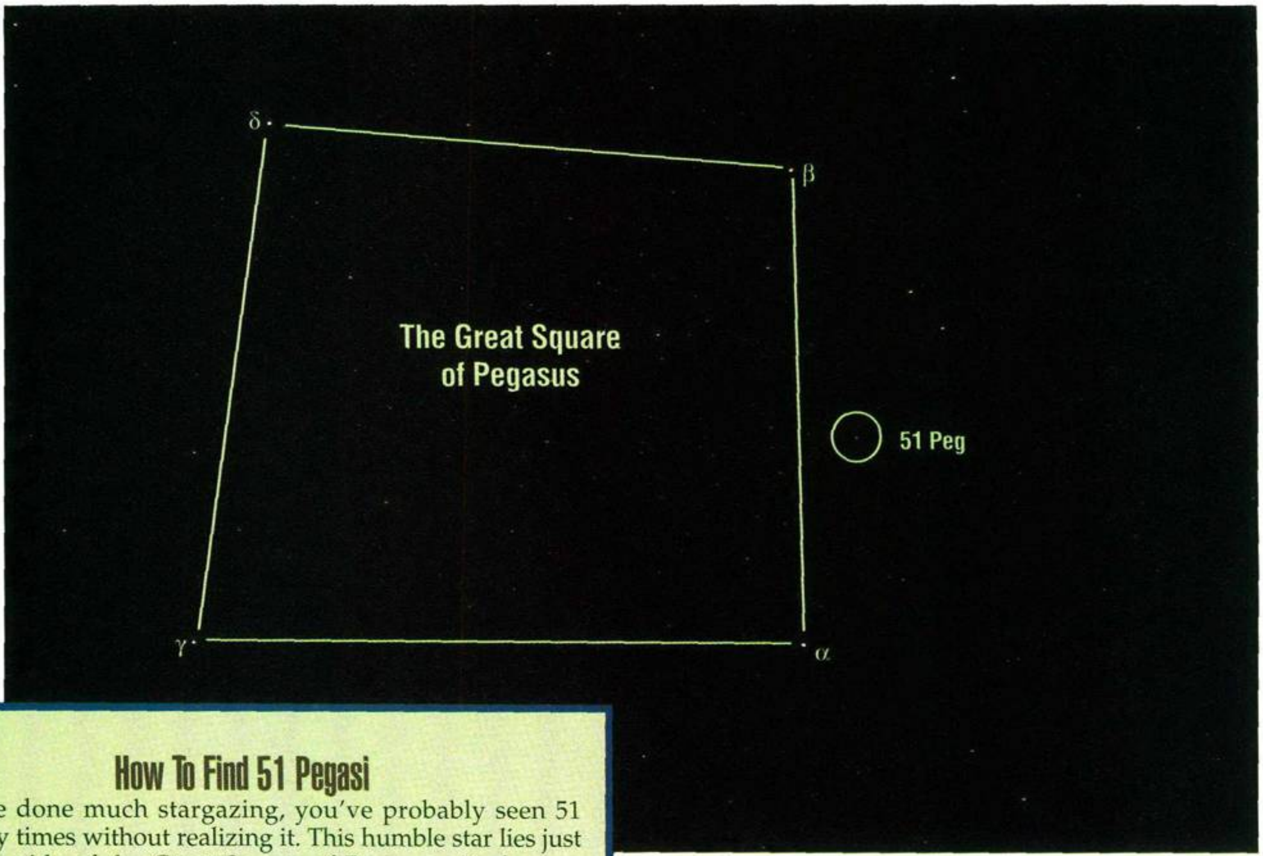


Steven A. Walther

How To Find 51 Pegasi

If you've done much stargazing, you've probably seen 51 Pegasi many times without realizing it. This humble star lies just off the west side of the Great Square of Pegasus, six degrees north-northwest of Alpha Pegasi, which is the star in the lower right corner of the Square in our photo above. At magnitude 5.5, it can just be seen with the unaided eye in a dark, haze-free sky. With binoculars, it becomes an easy target. Its distance, somewhat disputed, lies between 55 and 60 light-years. Although three billion years older, more rich in metals, and slightly larger than the Sun, 51 Pegasi is similar enough to be considered nearly a solar twin. And now that we know it has at least one planet going around it, we can say this star resembles the Sun in another important way.

As March opens, we find the Great Square rising just before dawn, which makes finding 51 Pegasi in the brightening twilight a bit of a challenge. Better conditions occur in late March and early April, as the mythical winged horse precedes the Sun and mounts into darker realms of the predawn sky.

By early May, however, Pegasus flies high above the eastern horizon well before dawn's precursory glow so 51 Pegasi can be seen without effort. Unfortunately, the same can't be said for the new planet, which is a billion times fainter and lies entirely within the glare of its parent star. — *Jeff Kanipe*

what it is and how it got there, that's an open question," says University of Arizona astrophysicist Adam Burrows. Astronomers will have to find more planets before they learn about the abundance of planetary systems and life.

Unexpected Planets

Prior to the 51 Pegasi discovery, planet hunters experienced years of frustration and witnessed many false alarms. Still, astronomers remained convinced that planets exist in large numbers. They have observed disks of gas and dust surrounding many young stars, and they think the planets in our solar system formed from colliding bodies in a disk such as these (see "Solar Systems in the Making," in Astro News, this issue). Computer simulations of planet formation almost always result in systems arranged much like our own: small, rocky planets orbiting close to the parent star with gas giants farther out. But with no planetary systems to study other than our own, no one can know for sure if these models depict reality.

Scientists are well aware that the universe is under no obligation to conform to their expectations. The first extrasolar planets were discovered where astronomers least expected them: around a pulsar. In 1994 Penn State University astronomer Aleksander Wolszczan reported conclusive evidence that three terrestrial-mass bodies orbit a pulsar, a collapsed remnant of a catastrophic supernova explosion (see "Second Chance Planets," January 1996). But these planets probably formed after the supernova by a process different than the one that created the planets in our solar system. Nevertheless, their existence indicates that planets can form in a variety of environments.

Rather than helping clarify astronomers' understanding of how planets form, the 51 Pegasi planet has muddled the situation even more. To say this planet is bizarre would be like saying that Mozart was a tunesmith. The planet orbits a mere 8 million kilometers from the star, 1/20th the Earth-Sun distance. It orbits so close to 51 Pegasi that its year lasts only 4.2 days. The star roasts the planet to a temperature of about 1,000 degrees Celsius, far too hot for life. If there were creatures on the planet, they would see a blazing star 30 times the size of the Sun.

Although astronomers haven't directly observed the planet yet, that hasn't stopped them from engaging in informed speculation about its nature. With the planet being so close to the star, some astronomers postulate that it is a giant ball of rock and iron, like a scaled-up version of the planet Mercury. But the planet has enough mass to hold onto a substantial atmosphere of water vapor, helium, ammonia, methane, and possibly hydrogen, so it could be a cousin of our own Jupiter or Saturn.

Mayor's and Marcy's observations indicate that the orbit is circular. Studies by Burrows show that the orbit is stable, meaning the planet may have been circling the star for billions of years. The star itself appears to be about 8 billion years old. Because it has about the same mass as the Sun but is more evolved, it is a little larger and brighter than the Sun. Despite being older than the Sun, the star is 20 to 50 percent more metal-rich than the Sun, metals in this case being elements heavier than hydrogen and helium. The metal excess may be a clue that will help astronomers figure out how the planet formed.

Tantalizing evidence in Mayor's data indicates that another low-mass object is orbiting 51 Pegasi. But it is unclear if this object is a planet, a star, or nothing at all.

How Did It Get There?

Computer simulations of planetary formation do *not* predict a planet with 160 to 600 times the mass of Earth orbiting a stone's throw from the parent star, so the discovery has sent astronomers scrambling for an explanation. Right now there are more educated guesses than hard-and-fast answers.

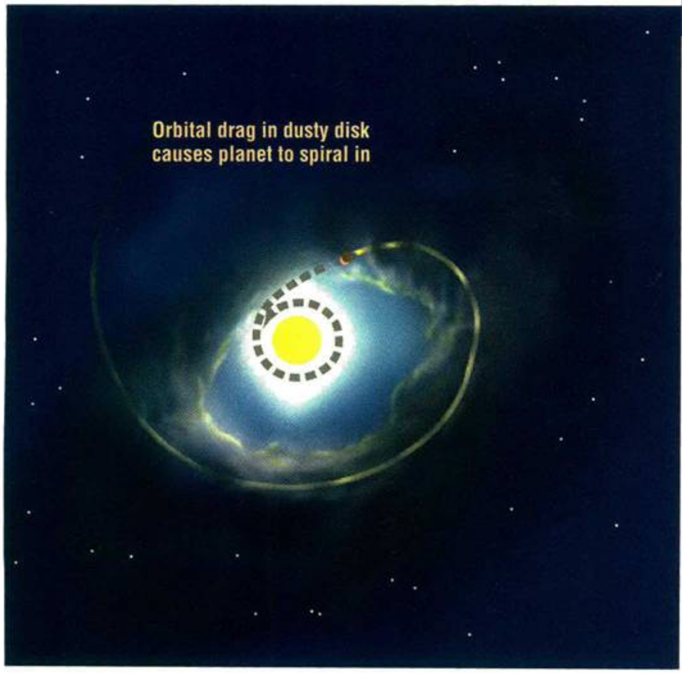
According to the standard planet-formation model, a star's searing temperature drives away all the lightweight gases in the inner disk, so inner planets form from leftover high-density materials like rock and iron. Because the inner disk has a small circumference, there just isn't enough rocky material to form large planets. Gas giants form in the outer disk, where temperatures are low enough to allow the gas to stick around. Because the outer disk is cold and has a large circumference, massive ice cores are able to form. When a core reaches a mass of about 10 or 20 Earths, its gravity is able to reign in the surrounding gas, allowing a planet to grow to gigantic proportions. Overall, this model beautifully explains why the inner planets in our solar system are small and rocky, and why the outer planets are large and gaseous.

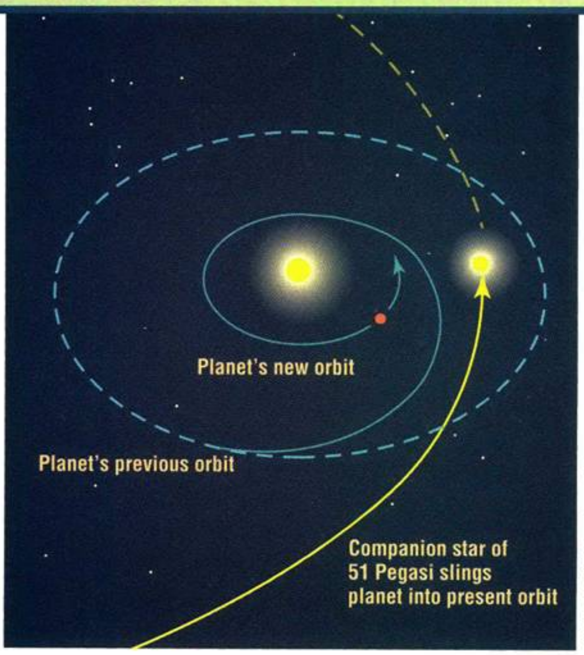
Because the star drives away the gas in the inner disk, the 51 Pegasi planet would be an enormous bowling ball of rock and iron if it formed at or near its present location. But Mercury — the innermost planet in our solar system — has a mass only 1/18th that of Earth. To form a planet even a few times more massive than Earth that close to the star, a disk would have to be thousands of times more massive than the disk that formed the planets in our solar system. Astronomers have never seen such a massive disk. "That would really perplex people as to how in the world you could put that much rock together," says Alan Boss of the Carnegie Institution in Washington, D.C., who models planetary formation.

The second possibility is that the planet is a gas giant like Jupiter or Saturn. If it is, there simply wasn't enough gas in the inner disk to form a giant gaseous planet. Moreover, there wasn't enough material that close to the star to form a core massive enough to accrete large amounts of surrounding gas.

A Migrating Planet?

If the original protoplanetary disk was more dusty than normal, it would have created a drag on the planet, causing it to spiral in toward 51 Pegasi (below left). On the other hand, the passage of a companion star might have gravitationally slingshot the planet closer in to 51 Pegasi (right).


Orbital drag in dusty disk
causes planet to spiral in



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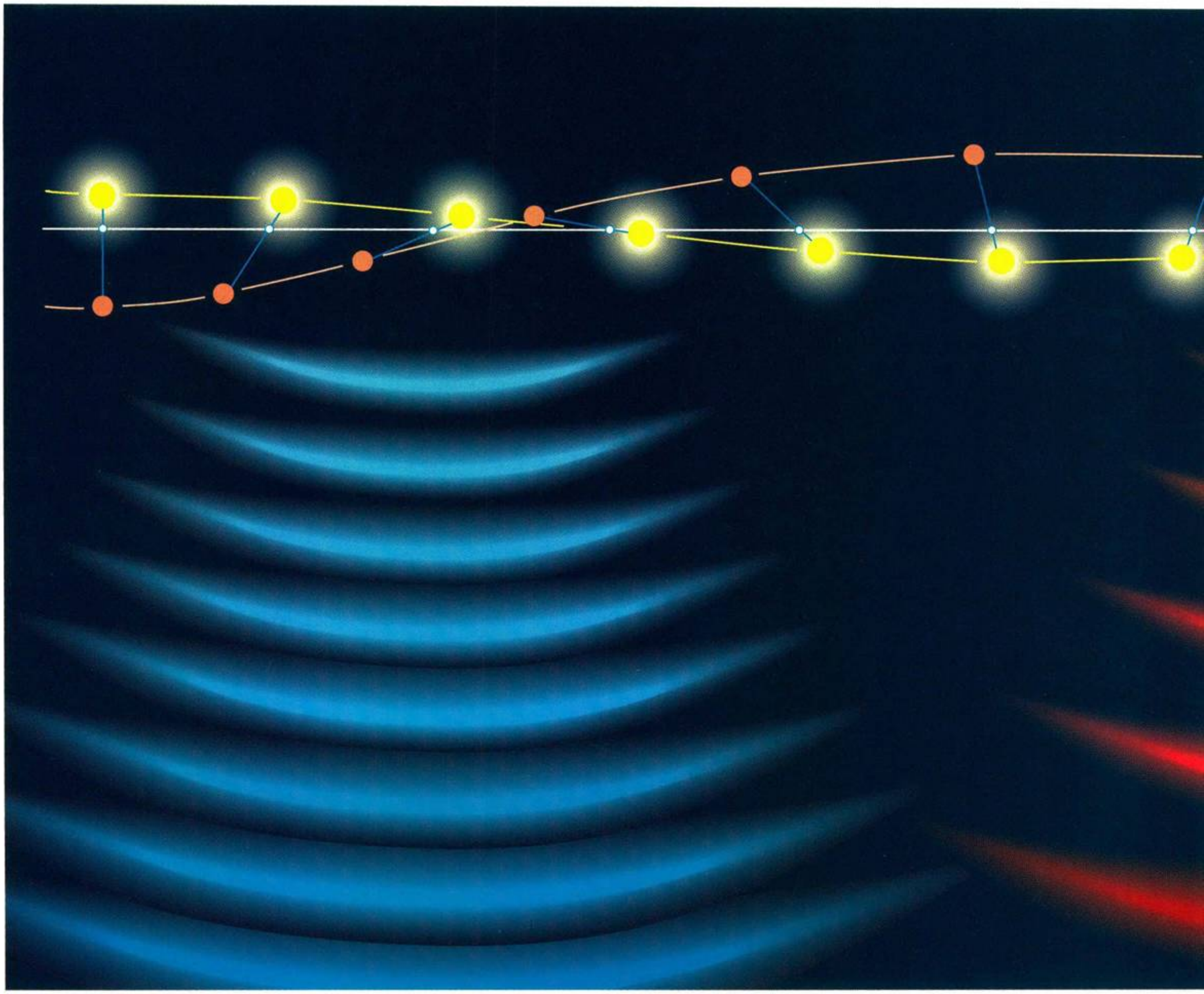


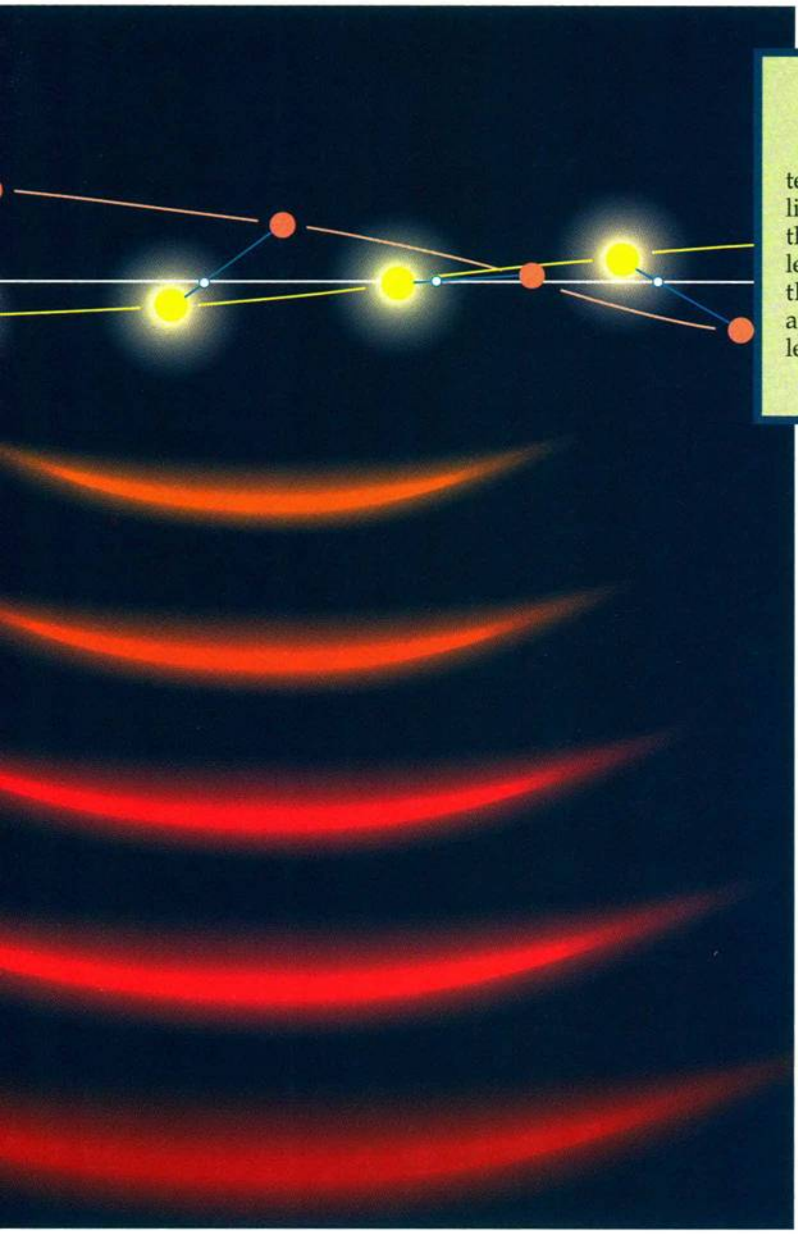
ASTRONOMY/ Lee Vande Visse

If this planet is a gas giant, it must have formed at least 100 times farther from the star and then somehow migrated inward. Astronomers have two ideas to explain how this migration could have occurred. One scenario proposes that billions of years ago, the planet passed too close to a companion star orbiting 51 Pegasi. The companion's gravity slingshot the planet towards 51 Pegasi. The planet may have skimmed the star's atmosphere, slowed down, and settled into its present orbit. This outcome is highly improbable but not impossible. Observations prior to 1995 had not indicated the presence of another star, but if the second companion is a star, it might be the smoking gun that makes this story appear more credible.

The other migration scenario is that the planet slowly creeped inward. The original protoplanetary disk might have been more dusty than normal, given the high metal content of the star. This would have created a drag on the planet, causing it to spiral inward. The planet might have eventually cleared a gap in the disk and settled into its current orbit, thus preventing it from spiraling all the way into the star.

An inwardly-migrating planet would be bad news for planet searchers (and by extension, those who search for radio signals from extraterrestrial civilizations). "Here's a case where a planet might have formed and moved like mad," says Boss. "What that may be telling us is that planets get scrambled, rearranged, and dragged in toward the star to such an extent that you might lose them. If this planet formed where Jupiter formed around the Sun and got pulled toward the star, whatever terrestrial planets were there, they went down the drain first — they're gone."

Another possibility is that the planet didn't form like a typical planet. Instead, it might be the remnant of either a dwarf star or a brown dwarf — an object more massive than a planet but not quite massive enough to be a star. Astronomers already know of hundreds of binary star systems whose two stars are as close together as 51 Pegasi is to its planet. Perhaps the planet was originally a stellar or brown dwarf companion in a binary system. Early in the larger star's life, in the so-called T Tauri phase, its furious stellar wind of charged particles would have bom-



Dance of Light and Motion

Both 51 Pegasi and its planet pivot around a common center of mass. The plane of this motion is nearly edge-on to our line of sight, so the star appears to move alternately toward then away from Earth. This motion is evident in the wavelength shift in the star's spectrum. When moving toward Earth the star's wavelengths are compressed, making the light appear blue shifted (far left). When moving away, the wavelengths are stretched out and the light appears red shifted .

barded the little guy, stripping its outer atmosphere and leaving behind a pseudo-planet. If this object is a stellar cinder, then it's highly questionable that it should even be considered a planet.

Astronomers will need more information about the mysterious object and the star before they can assess the competing models. Unfortunately, it will be very difficult to image the planet. The planet is only 3 milliarcseconds from the star and is 100,000 times fainter. Even the Hubble Space Telescope can't resolve the planet in the star's glare. When astronomers finally do observe it and learn about its physical properties and chemical composition, it may very well turn out that none of these models even comes remotely close to describing what actually happened at 51 Pegasi.

How To Catch a Planet

Whatever this planet is, and however it formed, it gives astronomers one more planetary system to compare to the two they already know about: our solar system and the pulsar planet system. But these three systems are completely different from one another, meaning astronomers can't use them to draw any firm conclusions about the preponderance of planets or the mechanism by which they form. "Theorists had been building systems like ours, but the discovery of the pulsar planets and the 51 Pegasi planet shows that planets can form in ways that theorists haven't figured out," says planet hunter William Cochran of the University of Texas at Austin.

To really understand planetary systems, astronomers will have to find more of them. Unfortunately, this is easier said than done. Detecting extrasolar planets presents astronomers with an enormous technical challenge. Although planets glow feebly in infrared light, they shine in the visible part of the spectrum only because they reflect a tiny fraction of the parent star's light. A star is roughly one billion times brighter than a planet. Even from a neighborly distance of 10 light-years, Jupiter would appear a tiny 1.7 arcseconds from the Sun, and its weak 23rd-magnitude glow would be swamped by the Sun's 2nd-magnitude glare. Earth would be fainter at 25th magnitude, and would lie only 0.3 arcseconds from the Sun.

Detecting the gravitational pull of a Jupiter-mass planet on its host star is an easier task, and this is exactly what Mayor and Queloz did. During one year of observing 51 Pegasi, they detected the orbital dance that the star and its planet perform as the two bodies move around a common center of gravity. Mayor and Queloz saw a repeating pattern in the star's spectrum indicating the presence of an orbital companion. The pattern repeats like clockwork every 4.2 days (the planet's orbital period), and the amplitude of the star's motion (about 55 meters per second) implies a planet with one-half to two times the mass of Jupiter.

The planet that orbits 51 Pegasi was ripe for the picking. It's so massive and so close to the star that its 55-meter-per-second pull on the star could have been *easily* detected by any one of a half-dozen other groups who look for the gravitational pull of massive planets on their host stars. The planet's 4.2-day orbital period helps as well. Astronomers only have to observe the star for a few nights to detect its motion.

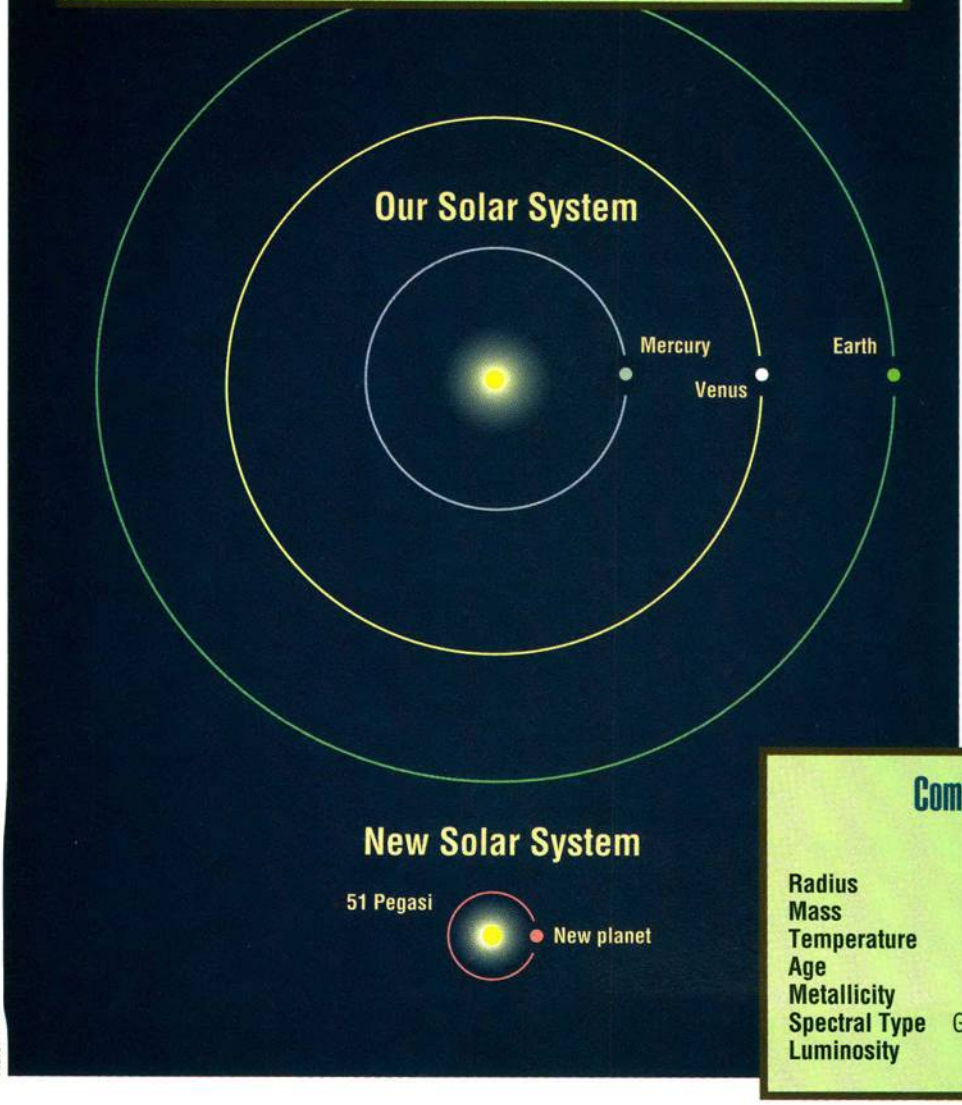
Most of these groups are armed with larger telescopes and superior detectors. The only reason this planet wasn't discovered sooner was that no one had bothered to observe 51 Pegasi. More than a decade ago the Canadian astronomer Bruce Campbell, who helped pioneer this type of planet search, had the necessary instruments to detect this planet. "If only he had pointed his telescope at this star in 1982, it would have just slapped him in the face," says Marcy.

Marcy, who conducts the most sensitive search for extrasolar planets, missed out on this discovery because the *Bright Star Catalogue* misidentified 51 Pegasi as a subgiant, a type of star whose pulsations mimic the motions caused by an orbiting companion. If he had known that it was a normal hydrogen-burning star like the Sun, he would have observed the star and found the planet. "Mayor and Queloz had a whole Swiss chocolate bar full of luck," he says.

But if this planet had instead orbited 51 Pegasi at Jupiter's distance from the Sun, most of the current searches wouldn't have been able to find it. The planet would pull too weakly on the star to be detectable. And its orbital period would be 12 years instead of 4.2 days, meaning astronomers would have had to monitor the star's spectrum for several years to see a pattern indicating motion.

Comparison of Planets

	Mercury	Earth	Jupiter	Saturn	51 Pegasi B
Mass	0.06	1.00	317.8	95.2	160 to 600
Diameter	0.38	1.00	11.2	9.5	3.5 to 16
Density (water=1)	5.4	5.5	1.3	0.7	0.2 to 20
Distance from Star	0.39	1.00	5.20	9.54	0.05
Orbital Period	88 days	1 year	11.9 yrs	29.5 yrs	4.2 days
Day Temperature (°C)	350	15	-150	-180	1000
Composition	iron rock	rock iron	H and He gas	H and He gas	?



Adler Planetarium

Where Are the Jupiters?

If more large planets orbited close to their star like the one at 51 Pegasi, these other groups would have turned up dozens of them by now. It's clearly an oddball. It's raising more questions than it's answering in regards to planet formation and the preponderance of life.

The discovery will motivate planet hunters to press on until they find *real* planetary systems. Thanks to new technology, planet-detection equipment has steadily improved. Over the past decade the various searches have been capable of finding planets slightly more massive than Jupiter at orbital distances comparable to Jupiter's or Saturn's distance from the Sun. A couple of the searches, including Marcy's, can now detect Jupiters and possibly even Saturns.

Astronomers once thought many stars were accompanied by Jupiters. But if that were true, dozens of Jupiters and super-Jupiters would have turned up by now. "In our 100 stars, planets with two to three Jupiter-masses would be easily detectable, and we haven't found them," says Marcy. "So they're not there, which means that solar systems in general rarely if ever form planets that are big brothers to our own Jupiter. And that in turn implies that Jupiter must be one of the heftiest planets in the planetary zoo."

While the observations haven't yet ruled out the existence of planets with

Comparison of Sun and 51 Pegasi

	Sun	51 Pegasi
Radius	1.0	1.4
Mass	1.0	0.95
Temperature	5500° C.	5430° C.
Age	4.6 billion yrs	8 billion yrs
Metallicity	1.0	1.2 to 1.5
Spectral Type	G2 (main sequence)	G3 (main sequence)
Luminosity	1.0	1.8

the same mass as Jupiter, many astronomers are beginning to wonder whether they are rare, like teenage Frank Sinatra fans. Radio observations of very young stars support this conclusion: most newborn stars are not surrounded by enough gas to enable Jupiters to form.

Still, astronomers remain confident in their planet formation models. And now that some of the searches are capable of detecting Saturns, astronomers expect a plethora of planets to start turning up in the next few years. As this issue went to press, it appeared that more planet discoveries would soon be announced.

Once astronomers find entire planetary systems, that will help theorists like Boss nail down the story of planet formation. "We're heading inexorably down a conclusion path," says Marcy. "That path says that a few stars may have a Jupiter-like planet. Probably many more stars have planets that are half a Jupiter-mass, more still have planets that are only a Saturn-mass, and so on." Boss adds, "We might find solar systems similar to ours, with terrestrial planets close to the star, but with four Uranus-mass objects sitting farther out. That would be absolutely unsurprising."

If astronomers are right, and a large fraction of stars harbor large planets, then they can conclude that the Galaxy has lots of Earth-size planets even before they have the technology to detect these smaller worlds. As Marcy notes, "If you can find a star with a Jupiter, a Saturn, and a Uranus thrown in for good measure, that would smell so much like our own solar system that you'd have a hard argument saying that there wasn't an Earth there."

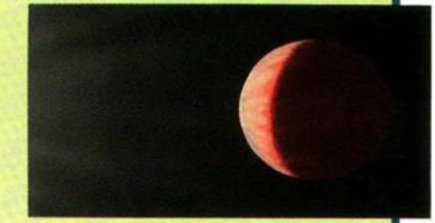
About the Painting

The painting was commissioned by ASTRONOMY magazine shortly after the announcement of the discovery of a planet around the solar-type star 51 Pegasi. I consulted with Adam Burrows at Steward Observatory, who was interviewed for the ASTRONOMY article. Burrows has been doing early calculations on the nature of such an object that is much closer to the star than Mercury is from the Sun.

Burrows had concluded that a planet is likely to hold an atmosphere if it is a rocky "terrestrial"-type planet instead of a gas giant, because the smaller radius in that case would produce more gravity near the surface. He also had concluded that the temperatures on such a planet could be molten.

I recalled from early theories about Venus (circa 1950s) that on a planet with one side facing a star, air would ascend at the point directly below the star (i.e., having the star at the zenith, called the substellar point) and descend at the point on the opposite side of the planet (the antistellar point). Adam thought circulation in the dense atmosphere could keep the night side molten. Tidal forces from the nearby star are also believed to create an elongated shape, with one side always facing the star.

Given these considerations, I made a portrait that shows an elongated planet, with the star off-stage but with the stellar glare just visible. The planet has a nearly opaque atmosphere, so that the surface is not visible, but the glow of the molten surface filters up through the atmosphere, causing an eerie glow from below the clouds on the night side. The atmospheric circulation and cloud patterns are assumed to run from ascending currents on the substellar point, around to the dark side, to a descending current node at the antistellar point. This portrait is based more on the terrestrial (rocky) models than the gas giant models, though the cloud circulation pattern might be similar in both cases. — *William K. Hartmann*



The next step will be to use interferometry to search for planets. Interferometers use special electronics and computers to combine the light from two or more small telescopes into the resolving power of a much larger telescope. A group headed by Mike Shao of the Jet Propulsion Laboratory has finished building an interferometer on California's Palomar Mountain. The interferometer consists of two 0.4-meter infrared telescopes spaced 100 meters apart, simulating the aperture of a 100-meter telescope. Shao's interferometer can detect gravitational perturbations on a star that are so tiny that planets as small as Uranus will stick out like sore thumbs (Shao says there's a possibility this interferometer can image the 51 Pegasi planet).

By the end of the decade, adaptive optics might even enable astronomers to do what was once thought impossible: take direct images of planets orbiting stars out to 30 light-years. Adaptive optics use computer-controlled deformable auxiliary mirrors to compensate for atmospheric distortion, enabling large ground-based telescopes to achieve the same resolution as the Hubble Space Telescope.

Although the 51 Pegasi planet might not be a planet in a conventional sense, astronomers should very soon start turning up bona fide planetary systems that include potentially habitable worlds. "What's exciting to me is that within the next three to six years we're going to have some information about the existence of planetary systems that in a way transcends all the academic disciplines," says Marcy. "The interest in their existence has implications for biology, religion, star formation, and our loneliness in the universe. So it's wildly profound that we're going to have answers to such an important question. I'm just on the edge of my seat wanting to know the answer." ☐

Robert Naeye (rnaeye@astronomy.com) is an associate editor for ASTRONOMY.

Far Journey to a NEAR Asteroid

Tantalized by passing glances at asteroids, NASA finally mounts its first mission to examine one up close. What they find will help write the book on solar system evolution.

by Jim Bell

For eons, asteroid Eros has drifted through the icy vacuum of interplanetary space, embraced in the timeless light of a billion stars. With a voice written in layers of pulverized rock and myriad craters, this tiny world has a story to tell. Its very essence holds volumes of solar system history for those who are willing to listen. Each hit of a meteorite, every glance from a cosmic ray, is duly preserved on a barren surface, perhaps back to a time when our Sun first burst forth as a star.

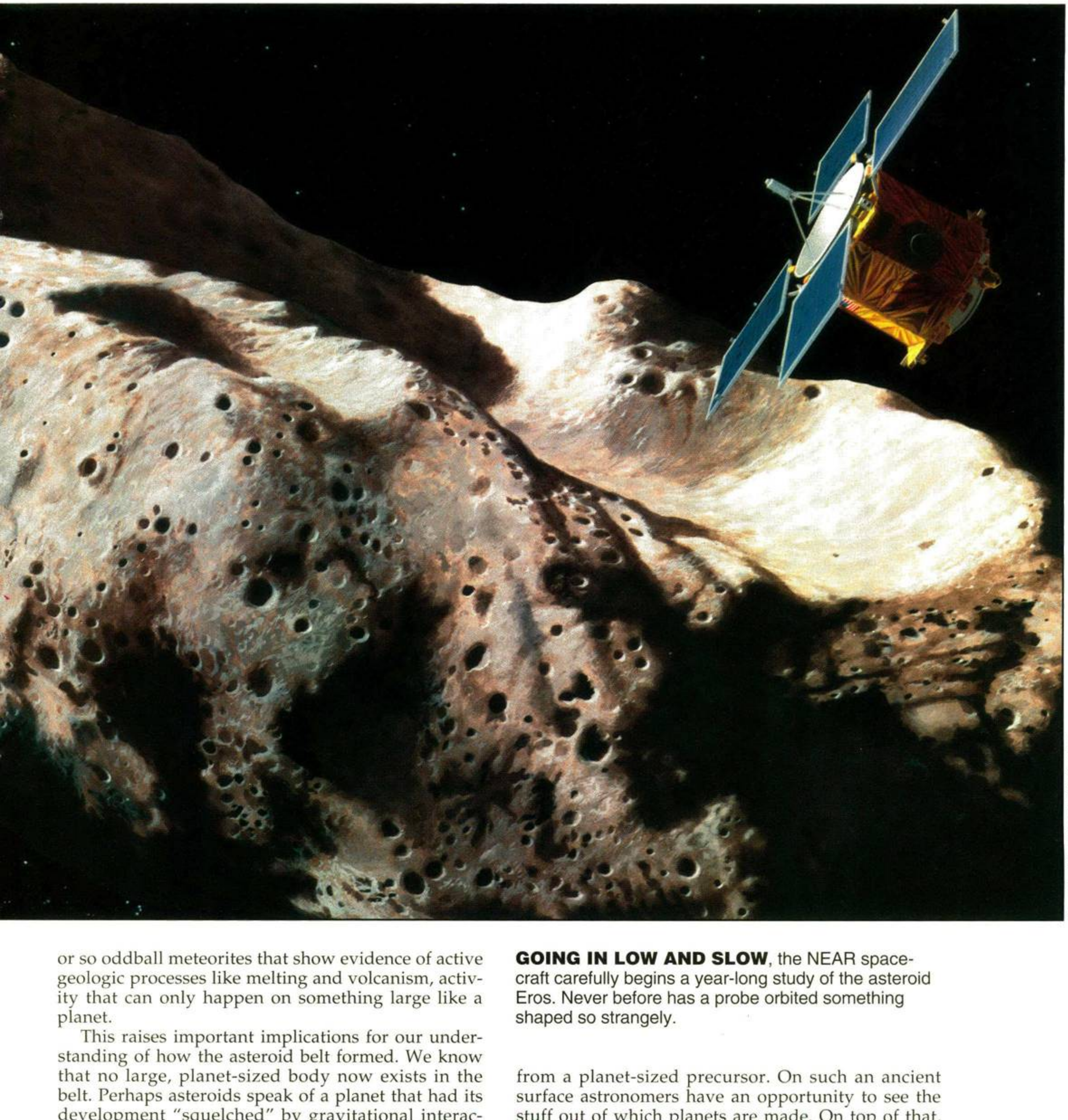
Now, an emissary from Earth is about to play back Eros' geological narrative. If all goes according to plan, on February 16, 1996, the Near Earth Asteroid Rendezvous (NEAR) spacecraft will launch from Cape Canaveral on a year-long, up-close examination of the asteroid 433 Eros. Once it arrives in early 1999, NEAR will direct a battery of six instruments to scrutinize Eros' surface in great detail. For the first time, humans will discover what an asteroid has to say about our mutual beginnings.

Why Study Asteroids?

Billions of years ago, asteroidlike objects called planetesimals collided, melted, and stuck together to spawn the planets. The asteroids we see today are essentially the leftover building blocks that failed to form planets. They underwent most of their evolution during the first few hundred million years of our solar system's history and then stopped. In that regard, asteroids are tiny pieces of the early solar system frozen in time.

Most of what we've gathered as to their nature comes from meteorites, which are thought to be the shattered flotsam from collisions between asteroids. They alone represent our only link to the asteroids.

Detailed laboratory studies reveal that more than 75 percent of the meteorites collected on Earth are blends of primitive silicate rock and metal unaltered since the formation of the solar system some 4.5 billion years ago. These "ordinary meteorites," called chondrites, stand in stark contrast to the 10 percent



Johns Hopkins University/Pat Rawlings

GOING IN LOW AND SLOW, the NEAR spacecraft carefully begins a year-long study of the asteroid Eros. Never before has a probe orbited something shaped so strangely.

or so oddball meteorites that show evidence of active geologic processes like melting and volcanism, activity that can only happen on something large like a planet.

This raises important implications for our understanding of how the asteroid belt formed. We know that no large, planet-sized body now exists in the belt. Perhaps asteroids speak of a planet that had its development "squelched" by gravitational interactions with Jupiter. A less likely may be that geologically active planetoids did form, only to break up later.

Only after studying an asteroid close up will scientists be able to gain insights into which scenario is true. A surface with volcanic rock would offer strong evidence for a planetoid break-up, for only large planetoids are geologically dynamic enough to sport volcanos. But if surface composition is consistent with the primordial chondrite meteorites examined on Earth, the asteroid most likely did not evolve from a planet-sized precursor. On such an ancient surface astronomers have an opportunity to see the stuff out of which planets are made. On top of that, an ancient asteroid's eons-long soaking in interplanetary space serves as a record of what the solar system's environment has been like for the last several billion years.

So a dedicated trip to an asteroid would not only help answer how the asteroid belt formed, but also open windows upon how our whole solar system came together as well. If the asteroid belt started out as a handful of large, planet-sized objects, why didn't it stay that way? What forces led to the objects' break-up? What were the implications for planetary development elsewhere in the solar system? When it comes to asteroids, scientists have no shortage of questions.

An Asteroid's Day in the Sun

For all the answers asteroids may offer, achingly little is known about their internal structure or surface geology. For the most part, they have been glimpsed only by the Galileo spacecraft as it blazed its way to a larger target: Jupiter. Its flyby of asteroids 951 Gaspra and 243 Ida revealed complex surfaces covered by craters, fractures, grooves, and subtle variations in color. Amazingly, Ida was even found to have a satellite now named Dactyl. However, Galileo spent only a few hours near each asteroid, and its instruments, optimized for science observations at Jupiter, were not capable of determining each asteroid's composition or origin.

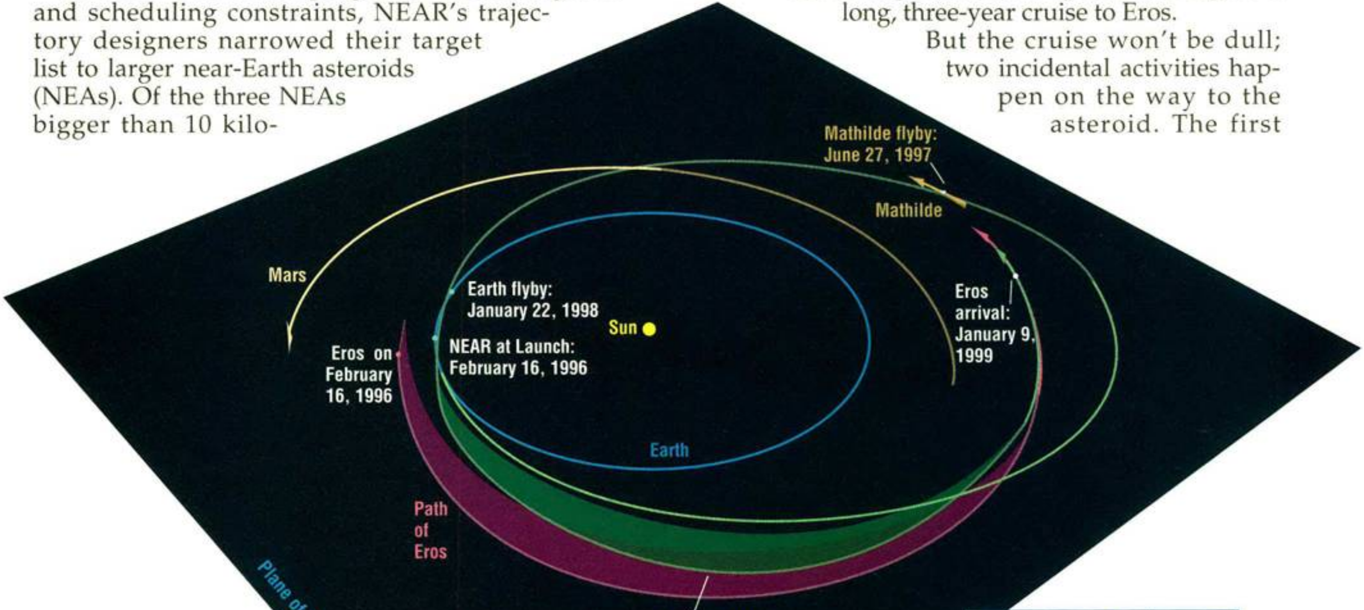
Realizing this need, NASA scientists resurrected a proposal that had been around since 1964 to study asteroids easily reachable from Earth. Such a mission would take advantage of a newly announced initiative called the Discovery program. In 1993, after a selection process that included a variety of other proposals, NASA gave the Johns Hopkins University's Applied Physics Laboratory permission to develop the NEAR mission as one of the space agency's first Discovery projects.

In order to meet the program's demanding cost and scheduling constraints, NEAR's trajectory designers narrowed their target list to larger near-Earth asteroids (NEAs). Of the three NEAs bigger than 10 kilometers in size, two were difficult to reach by spacecraft. Asteroid 433 Eros, the largest and easiest NEA to get to, was chosen as the most logical object for the NEAR mission.

As it turns out, Eros has been the subject of a long and rich observational history. During one particularly close pass to Earth in 1975, light-curve data revealed Eros to be cylindrical in shape with a rotation period of 5.27 hours. Astronomers also found that the asteroid spins on its side, like the planet Uranus. Spectroscopic observations showed mineralogical differences between the two sides of Eros, possibly caused by the impact of another asteroid. Radar data also suggested that a recent impact spalled off a huge chunk of Eros to unveil fresh or unaltered material. These tantalizing Earthbound views only serve as a prelude to wonders that await NEAR in 1999.

To get there, NEAR must perform what's best described as a celestial ballet between Earth and Eros. Celestial mechanics presents a rare opportunity for an encounter with Eros during a 16-day window between February 16 and March 2, 1996. NEAR's launch on a Delta-II rocket is planned for the first day of that window. The probe ascends directly into interplanetary space without even the benefit of a parking orbit around Earth. Within a few hours of launch, it's already looking over its shoulder to get a small set of calibration images of the Moon. After the farewell pictures, the spacecraft begins a long, three-year cruise to Eros.

But the cruise won't be dull; two incidental activities happen on the way to the asteroid. The first

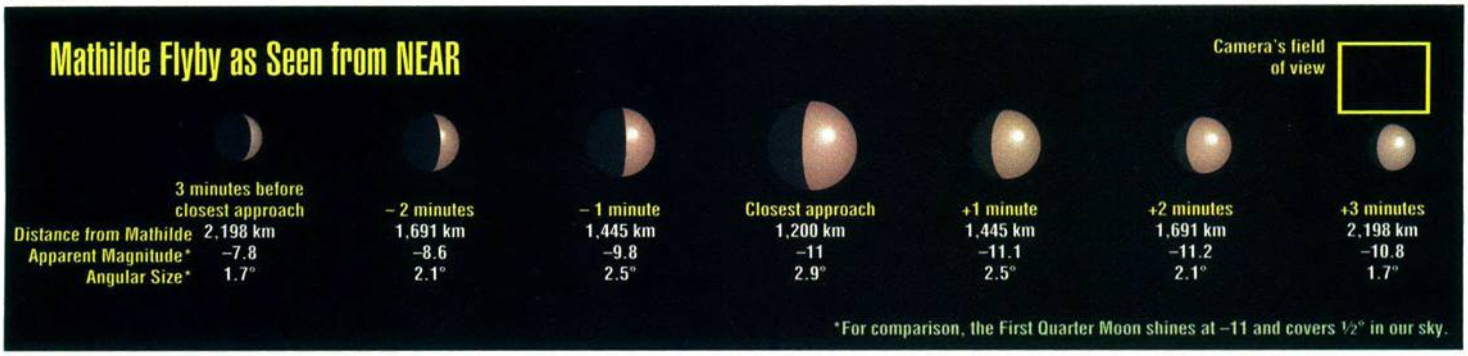


Guy Ottewell, Astronomical Workshop

NEAR's Long and Winding Road to Eros

GETTING THERE is half the fun for asteroid-bound NEAR. Its path (green) passes Mathilde and Earth before reaching Eros (purple path). Colored areas are where NEAR and Eros lie below the plane of the solar system.

JHU/APL



Mathilde Flyby as Seen from NEAR

	3 minutes before closest approach	– 2 minutes	– 1 minute	Closest approach	+1 minute	+2 minutes	+3 minutes
Distance from Mathilde	2,198 km	1,691 km	1,445 km	1,200 km	1,445 km	1,691 km	2,198 km
Apparent Magnitude*	–7.8	–8.6	–9.8	–11	–11.1	–11.2	–10.8
Angular Size*	1.7°	2.1°	2.5°	2.9°	2.5°	2.1°	1.7°

*For comparison, the First Quarter Moon shines at –11 and covers ½° in our sky.

ASTRONOMY: Thomas L. Hunt, after Anne Harch

involves a bit of serendipity and a touch of irony. Even though NEAR is designed to study an asteroid in more detail than previous flybys have allowed, the mission has its own fast encounter with a different type of main-belt asteroid.

During the process of defining a route to Eros, mission designers discovered that if NEAR launches before February 27, it will pass within 1,200 km of 253 Mathilde on June 27, 1997 (see "A NEAR Glance of Mathilde"). Mathilde is a large asteroid that falls into a completely different class than Eros. On top of that, Mathilde was recently discovered to be rather spherical and rotating extremely slowly. Just how it ended up with a lazy, 17 Earth-day rotation period is, for the time being, anybody's guess.

The second bit of midcruise excitement happens on January 22, 1998, when NEAR uses Earth's gravity to slingshot itself to Eros. The flyby also bends NEAR's orbit into the same plane as the asteroid. In the space of a few hours the spacecraft passes within 478 km of Earth, crossing over Hawaii and much of the South Pacific and Antarctica at closest approach. During that time, scientists will verify the calibration of NEAR's instruments, a task last done when the spacecraft was near Earth almost two years earlier.

Science team members plan to use the Moon's known composition as a spectral yardstick for the spacecraft's imager. "The seven different filters we image through reveal mineral compositions at Eros," says imaging team member Scott Murchie. "Shooting calibration pictures at the Moon, a surface that's been scrutinized by similar filters both from Earth and other spacecraft, lets us measure the fidelity of our imager and its filters after they've been soaking in space."

NEAR Meets Eros

Less than a year later, and halfway across the inner solar system, NEAR finally arrives at its target. On January 9, 1999, the spacecraft slows to a velocity of only 5 meters per second relative to Eros and flies to within 500 km of the asteroid. Thus begins a series of loping, confidence-building orbits, each closer than the last, to measure the asteroid's gravity and better define its shape. Eventually the craft settles into a 100-km intermediate orbit, dipping to within 35 km during various science-gathering runs.

Planning and executing these orbital maneuvers on such a small, unknown object is an unprecedented challenge for spacecraft navigation experts. One of them is the Jet Propulsion Laboratory's Robert Williams, who's been planning spacecraft orbits since the days of Viking more than 20 years ago.

"At a size of roughly twice that of Manhattan, Eros is the smallest object in space we've orbited," says Williams. "Its escape velocity of 5 meters per second means one badly timed pulse of a thruster could kick the spacecraft out of orbit, or worse, propel it into the surface." To make matters more complex, Eros has an oblate shape measuring 40 by 14 by 14 kilometers. Never before has a spacecraft orbited something that isn't round.

But there is one powerful tool available to Williams and his navigation team. Monitoring spacecraft motion through the Doppler shift of its radio

A NEAR Glance of Mathilde

"We'd have to do more work just to make sure we wouldn't hit it!"

That's how one NEAR mission planner jokingly justified including a golden opportunity to study asteroid Mathilde on the way to Eros. On June 27, 1997, the NEAR spacecraft, traveling some 10 km per second, passes just 1,200 km from 61-km-wide Mathilde. For mission planners guiding a spacecraft halfway across the solar system, such a close pass better qualifies as a near miss.

Since the spacecraft passes so close anyway, the thinking went, why not take a peek at what's there? Doing so wouldn't waste precious fuel or put a ding in NEAR's frugal budget. Approval was given.

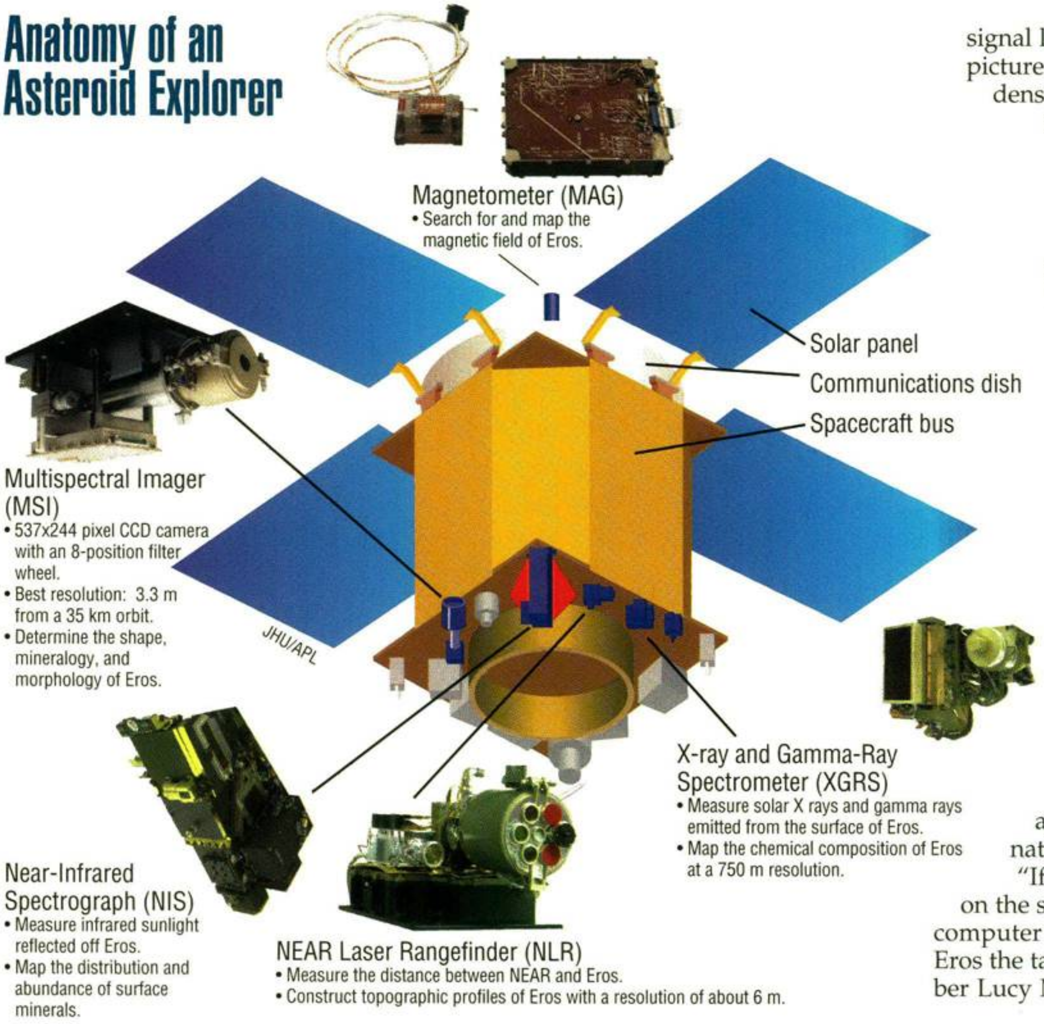
It turns out encountering Mathilde contrasts beautifully with what mission scientists expect to see at Eros. Oblong Eros, about 40 km in length, periodically passes just inside the orbit of Earth and is thought to be rich in metallic minerals. On the other hand, round Mathilde, a darker asteroid that may be replete with carbon compounds, stays within the main asteroid belt. Enigmatic Mathilde also has a "day" of 17 Earth days, one of the slowest rotation rates ever found for an asteroid. Random meteoroid impacts can't account for a period that slow.

But if scientists want an answer to this and many other riddles about Mathilde, they will have to work fast. Although scientists enjoy the luxury of studying Eros for a full nine months from orbit, the Mathilde flyby wraps up in less than half an hour. And where Eros gets a full battery of instruments directed at it, there's only time at Mathilde to take a few dozen or so pictures.

NEAR's CCD camera starts snapping just eight minutes before closest approach. For five minutes on either side of closest approach, the spacecraft shoots a sequence of images that should show detail down to 200 meters.

The picture-taking sequence wraps up about 20 minutes after closest approach. Then NEAR goes into hibernation until January 1998, when it flies by still another body in our solar system that's both picturesque and enigmatic: Earth.

Anatomy of an Asteroid Explorer



Magnetometer (MAG)
- Search for and map the magnetic field of Eros.

Multispectral Imager (MSI)
- 537x244 pixel CCD camera with an 8-position filter wheel.
- Best resolution: 3.3 m from a 35 km orbit.
- Determine the shape, mineralogy, and morphology of Eros.

X-ray and Gamma-Ray Spectrometer (XGRS)
- Measure solar X rays and gamma rays emitted from the surface of Eros.
- Map the chemical composition of Eros at a 750 m resolution.

Near-Infrared Spectrograph (NIS)
- Measure infrared sunlight reflected off Eros.
- Map the distribution and abundance of surface minerals.

NEAR Laser Rangefinder (NLR)
- Measure the distance between NEAR and Eros.
- Construct topographic profiles of Eros with a resolution of about 6 m.

signal lets scientists construct an accurate picture of Eros' shape, gravity, mass, and density. Combined with NEAR's high-fidelity pictures of Eros, the navigation team will use this information to construct a computer model that predicts the spacecraft's motion in various orbits. The team plans to update this computer asteroid model weekly as the mission progresses.

And in yet another first in spacecraft exploration, NEAR has a version of this model loaded into its onboard computer. This helps streamline instrument-pointing moves the spacecraft must make. Each orbit, along with any maneuvers required by the science teams during data collection, has a dry run on Earth to catch any pitfalls. Then the commands are radioed to NEAR, where an onboard computer plots them against its model of Eros to coordinate where and when to point.

"If we want NEAR to image object A on the surface, we merely tell the onboard computer where on its computer model of Eros the target lies," says science team member Lucy McFadden. "Then as we pass over

Doing it the Discovery Way

"Faster, cheaper, and better."

It's NASA's new way of conducting planetary exploration. And as you read this, the first mission that embodies this new direction, the Near Earth Asteroid Rendezvous (NEAR) mission, is poised for launch at Cape Canaveral. NEAR is the first of what is hoped will be many spacecraft to fly in NASA's Discovery program.

Discovery's rules of the game state that mission proposals cannot exceed a price tag of $150 million. That includes the costs of design and building a spacecraft, launching it, and running the mission for 30 days after it reaches its target. Only three other missions have survived the program's uncompromising selection process: one called Stardust that collects material from a comet and returns it to Earth, a mission to Mars called Mars Pathfinder, and a lunar orbiter called Lunar Prospector.

NEAR project manager Tom Coughlin recalls his program's competition experience was both rigorous and beneficial.

"As a project manager I found the discipline this process injected into designing a mission most refreshing," say Coughlin, whose experiences include pulling together spacecraft for the Strategic Defense Initiative, or Star Wars, program. "The whole mission, its hardware and science, was extremely planned and optimized. Gone were the last-minute management and budgetary hassles that came from having to wedge in last-minute experiments or observations. And if there were any changes proposed, we had to work within well-defined hardware and financial constraints."

Such was the case when planners discovered NEAR's Mathilde flyby opportunity. Taking advantage of it could not change the spacecraft's design, Coughlin says. Also, the team couldn't devote significant time to planning the Mathilde flyby until after NEAR's launch. Until then, the only thing on our plate dealt with Eros.

Does the Discovery philosophy offer enough wiggle room for opportunities like NEAR's Mathilde flyby?

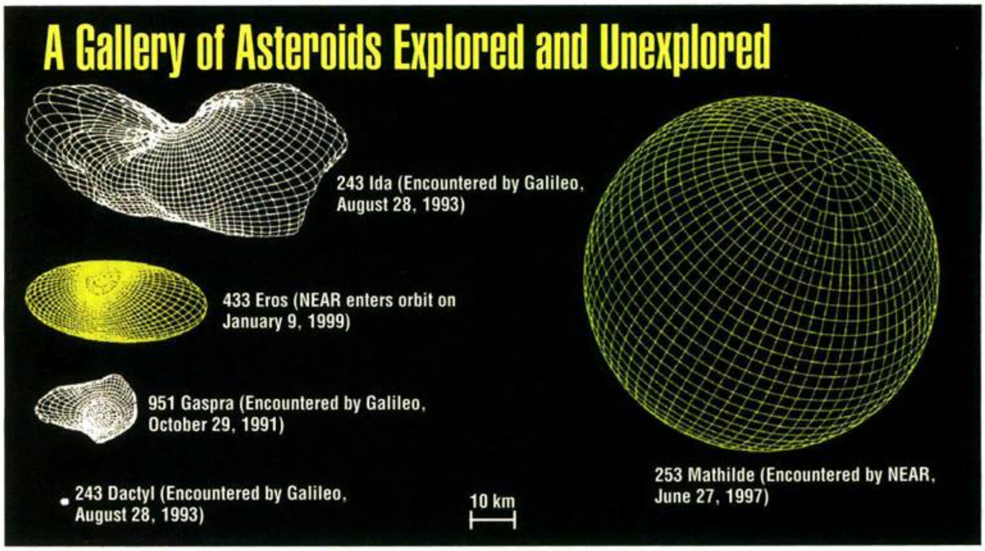
"Yes," he says. "We've proven it does. But each and every mission's going to have to reconcile that dilemma itself. We did because somebody saw the opportunity well enough in advance for us to budget. We also didn't let Mathilde detract from our primary goal, which was Eros."

As for whether the new philosophy precludes extended missions in order to save money, Coughlin is also pragmatic. "That'll have to be decided case by case," he says. "Perhaps if such a possibility occurs to mission planners, it might serve as an incentive to 'underrun' development costs, yielding smarter, tighter designs."

So goes a new paradigm for 21st-century planetary exploration: Smarter — not bigger — is better.

that region, the spacecraft will maneuver by itself to center attention on that feature."

Pointing the spacecraft during these minute adjustments uses the torque generated by four internally mounted "reaction" wheels. If a combination of these spinning wheels are commanded to spin at a different rate than the others, the spacecraft softly twists on its axis. By adjusting spin rates appropriately, NEAR's onboard computer subtly nods the spacecraft in any direction necessary to optimize science collection.


A Gallery of Asteroids Explored and Unexplored
243 Ida (Encountered by Galileo, August 28, 1993)
433 Eros (NEAR enters orbit on January 9, 1999)
951 Gaspra (Encountered by Galileo, October 29, 1991)
243 Dactyl (Encountered by Galileo, August 28, 1993)
10 km
253 Mathilde (Encountered by NEAR, June 27, 1997)

JHU/APL

Adding to an understanding of Eros' attributes is an onboard laser rangefinder that measures NEAR's distance from the asteroid to an accuracy of about 6 meters. It operates like a radar, sending out short bursts of laser light and then recording the time it takes the signals to return. From this information scientists can construct detailed topographic profiles of Eros.

Each profile is woven together to better determine the asteroid's overall shape which, when combined with gravity mapping deduced from the spacecraft's motion, sheds even more light on Eros' internal structure. Findings from this type of study will answer whether Eros is an amalgam of fragments or a single piece from an ancient planetoid.

NEAR's magnetometer weighs in on this issue too; if the instrument detects a magnetic field, Eros might have its origins in a shattered, homogeneous miniplanet. Incidentally, Galileo's magnetometer found tantalizing hints of a magnetic field during its flyby of Gaspra and Ida, asteroids in the same class as Eros.

Beauty That's Skin Deep

Detecting a coherent magnetic field would be just one milestone in NEAR's $120 million quest to figure out Eros' origin. Other clues lie locked in the types of rock and soil that cover the asteroid's surface. To garner them, NEAR comes loaded with an imager, a near-infrared spectrograph, and the XGRS, a spectrometer that detects X rays and gamma rays. These three tools will team up to construct a complete mineralogical and elemental survey of Eros.

The XGRS measures X rays and gamma rays that come from Eros' surface. The asteroid's soil emits these rays after absorbing charged particles from the Sun and being bombarded by cosmic rays. Measuring these emissions lets scientists deduce what elements lie embedded in Eros' soil. To figure out what minerals make up Eros' surface, scientists use NEAR's near-infrared spectrograph.

By folding together what the two instruments tell them, scientists will make direct comparisons to meteorites collected on Earth. A compositional match with ordinary chondrite meteorites might clinch a theory that Eros and other asteroids are primordial pieces of a planet that never formed. Such unaltered material could date back to the beginning of the solar system.

One more instrument, a CCD camera fitted with seven colored filters, also maps mineral abundances. Imaging Eros through each specialized filter reveals the presence of certain rocks and minerals. When it's not shooting through spectral filters, the camera gives planetary scientists white-light pictures worth well more than the proverbial thousand words. From an orbit of 35 km, the camera will glean details in craters, ridges and grooves as small as 3 meters across.

Such resolution will let scientists look at Eros' landforms and figure out how its surface has weathered. For the past several billion years, Eros has been a big piece of cosmic fly paper, sweeping up whatever lies in its region of interplanetary space. Locked in its cratering record is a history of conditions that influenced Earth and other inner planets. Over the eons, cosmic rays, impacts, and particles from the Sun have altered the chemical nature of Eros' soils. Such an invaluable record should tell planetary scientists what the inner solar system's environment has been like for the last several billion years.

The Shape of Things to Come?

This detailed study of Eros' tortured surface might hold great implications for humanity. Earth's neck of the solar system isn't always a friendly place for fragile forms of life. It was an asteroid roughly half the size of Eros that hit our planet 65 million years ago and extinguished many species of plants and animals, including the dinosaurs. NEAR's encounter with Eros represents our first chance to look at a near-Earth asteroid, one that embodies a threat humans may someday have to overcome.

Looked upon in this way, NEAR's mission to Eros takes on a dual purpose. It allows us to think through our planetary origins while contemplating a more proactive human future. With a history that spans the ages, tiny Eros will speak with a clarion voice as compelling as any other planet in our solar system. ☐

Jim Bell is a planetary scientist at Cornell University. He thanks fellow NEAR science team members Mark Robinson of the U. S. Geological Survey and Andy Cheng, the NEAR project scientist at the Johns Hopkins University Applied Physics Laboratory for their assistance in writing this article.

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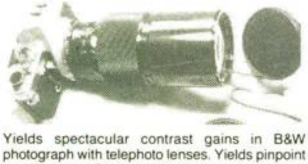

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2" (1.83" mirror)(see photo above) **$169.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

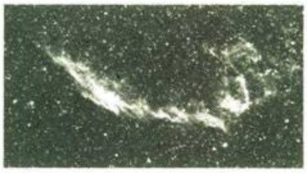
"Consistently performed well on all emssion and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces **$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces **$79.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS **$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography **$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16) **$299.50**
2" Rear Cell Filter, fits SCT's Deep-Sky, **$119.50** UHC, O-III, H-Beta, **$199.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces **$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces **$199.50**
DEEP-SKY and choice of **UHC, O-III or H-BETA** Filter (**Save 11%**) 1¼" **$159.50**; 48mm **$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼" $99.50, 48mm $199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm **$7.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece **$19.50**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece **$25.00**
**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595**

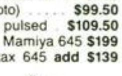
Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$189.50**
48mm Coma corrector/field flattener **$285**
3X Relay Diagonal (see photo) **$99.50**
Illuminated reticle eyepiece, pulsed **$109.50**
Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

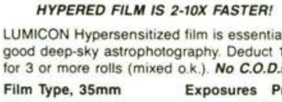
For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** **$109.50** Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left)
6. **LUMICON 48mm DEEP-SKY FILTER** **$119.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

HYPERSENSITIZED FILM



HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$14.95**
Kodak Gold 1000 fast, fine grain	12	**$13.95**
Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

CIRCLE NO. 45 ON THE READER SERVICE CARD

LUMICON® ACCESSORIES MEADE® TELESCOPES

TOLL-FREE ORDER LINE 1-800-767-9576 EXPERT INFORMATION 1-510-447-9570 FAX 1-510-447-9589
LUMICON, 2111 Research Drive, Suites 4-5, Livermore, CA 94550 OPEN M-F 9-5, SAT 9-1 PST

LED FLASHLIGHT . $14.95

LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

LUMILITE red LED flashlight	**$14.95**

DRIVE CORRECTORS

LUMICON UNITRAK DRIVE CORRECTOR

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

Unitrak™ single-axis corrector	**$99.95**
LUMICON DX200 dual-axis correc.	**$249.00**
DX2BP incl. battery & charger	**$298.00**
Convenient rechargeable Porta-Pac battery: 12V DC Porta-Pac (5AH) & recharger	**$89.50**

48MM COLORED FILTERS

FOR EVERY NEED

Select 48mm UV, Red, Yellow, Green (ea.)	**$24.00**
48mm Cyan (absorbs red)	**$69.00**
48mm High Performance Blue (95% T)	**$49.00**
48mm Tri-Color Blue (80% T- 400nm)	**$49.00**
48mm Ultraviolet (85% T- 370nm)	**$49.00**
Color Separation Set: cyan, red, yellow, blue	**$149**

RICH FIELD! 2° in 8'' SCT

NOW ONLY

$99.50

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.50**
Giant Rich-Field Viewer (10-14'')	**$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $439**
Meade 40mm 2'' Wide-Field†	2.4°	**add $498**

†Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PROTECTIVE DUST COVERS

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser			**4/$2**
2'' O.D. plug	**2/$2**	3½'' O.D. plug	**$1.50**
1¼'', 1⅜''	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''*	**$20**
2⅛''	**2/$20**	15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

MEADE 8'' - 16'' LX200

NEW! 8'' - 10'' LX50

8'' LX50

$1495

16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller. **LX200** - full computer control w/64K obj. mem. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200 Schmidt-Cassegrain.

NEW! 8'' LX50 w/wedge, tripod, hand controller ($115 P&S)	**$1495**
8'' LX200 w/computer ($105 P&S)	**$2495**
Wedge for photographing w/8'' LX200	**$139**
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1595**
10'' LX50, f/10 w/wedge, tripod, dec. motor, hand controller ($145 P&S)	**$1795**
10'' LX200 w/computer ($145 P&S)	**$2895**
12'' LX200 (f/10 only)($215 P&S)	**$3995**
Super Wedge for photogr. w/10'',12'' LX200	**$395**
16'' LX200 f/10 w/tripod ($385 P&S)	**$14,950**
Dew Shields: 8'' **$119;** 10''	**$129**
12'' **$189;** 16''	**$289**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4'' f/10 w/motor ($40 P&S)	**$699**
Model 2120B 10'' w/wedge, tripod	**$1599**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4'', 8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10	**$395**

MEADE STARFINDERS

8'' f/6

$699*

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$325**
6'' f/8 Equat. Starfinder 6(add $79 P&S)	**$599**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$425**
8'' f/6 Equat. Starfinder 8 (add $89 P&S)	**$699**
10'' f/4.5 Dobsonian Starfinder ($85 P&S)	**$595**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$799**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$795**
16'' f/4.5 Dobsonian Starfinder (freight COD)	**$1095**
16'' f/4.5 Starfinder 16 (ship. freight COD)	**$2495**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector	**$99**
Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination	**$475**

SKY VECTOR™ $249!!

Includes Computer, Encoder, Hardware

LOW PRICE—from $249

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $249

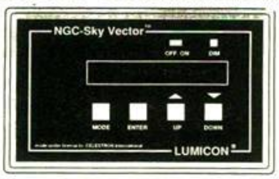
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $289

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $389

IMPROVED!—5500 Additions / Corrections



Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7	**$129.00**
2'' Adapter for Hasselblad	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

LUMICON ACCESSORIES

LUMICON. Livermore. CA 94550 (510) 447-9570 FAX (510) 447-9589

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS

New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' **adapter** w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, right-angle	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER	**$199.50**
1¼'' right-angle version, w/star diagonal	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$49.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc.	**$29.50**
2'' adapter for C-80, C-100 refractor	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

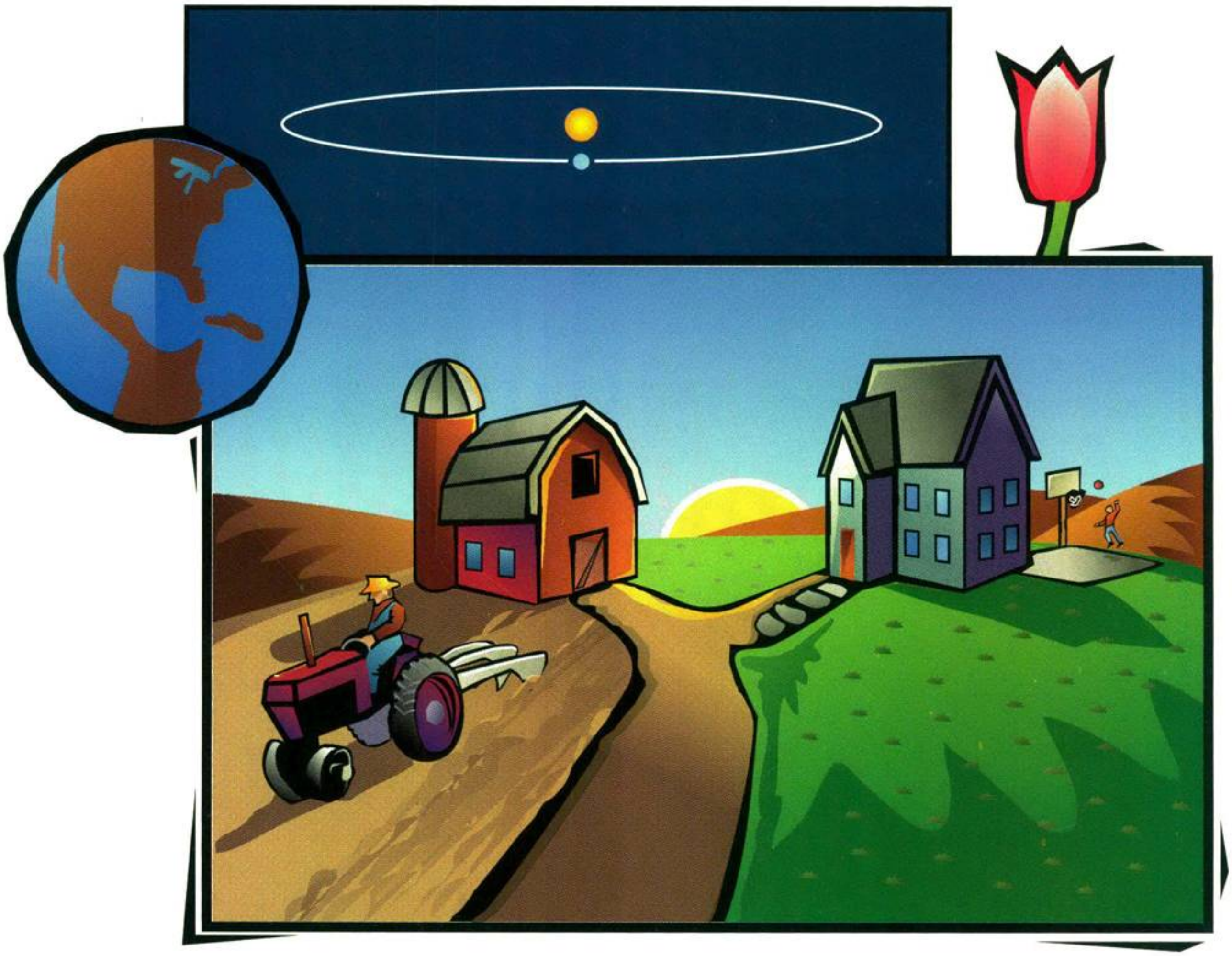
EXTENSION TUBES

1'' long 1¼'' OD thread-in extension	**12.00**
2½'' long extension (holds 1¼'' filters)	**19.50**
4½'' long extension for 1¼'' eyepieces	**$25.00**
3'' long extension for 2'' eyepieces*	**$29.00**
2'' long extension for 2'' eyepieces*	**$29.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing,threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*



PATHFINDERS

TILT-A-WHIRL ASTRONOMY

The Seasons Explained

Some liken Earth's leisurely motion around the Sun to a slow dance. In fact, it has more in common with a wild carnival ride. Hold on, we're going for a spin!

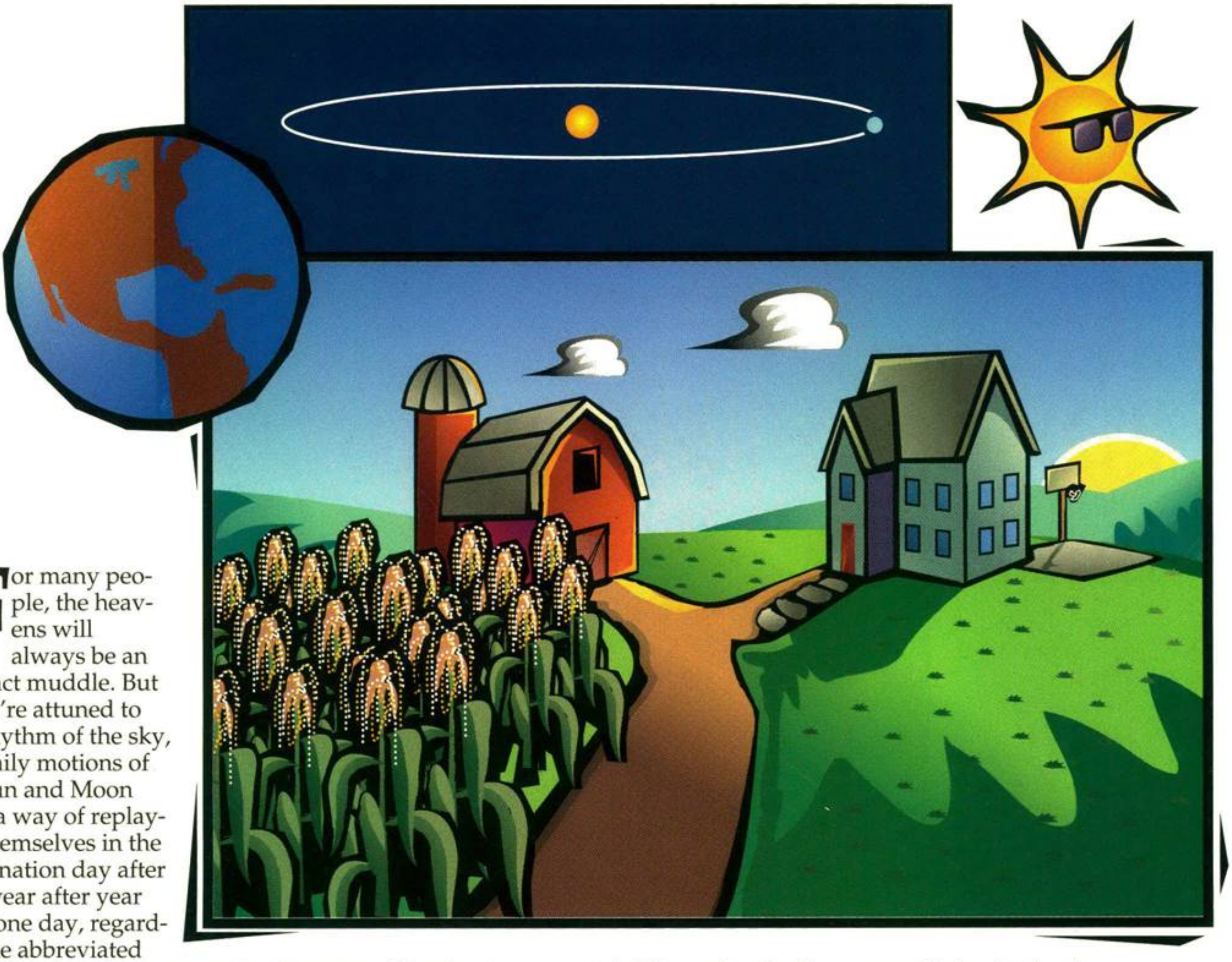
by Jeff Kanipe

When I was a kid working at my high school planetarium, I marveled at the way the operator could speed up the heavens to a dizzying pace. A month's worth of motion could be displayed in a few minutes just by twiddling a knob. The Sun would race across the dome like a giant roulette ball, ever skirting the Moon in its eastward motion.

If you watched a year's worth of this motion in a quarter of an hour or so, you noticed something else. In December, the Sun arced across the southern part of the artificial sky, popping up from behind the grain elevator silhouette, but rapidly setting near the hill with the cow on it. A few minutes later in June, it rose from a grove of black trees standing north of the grain elevator and set behind the outline of the barn, north of the cow.

When you make the Sun move *prestissimo* across a planetarium's sky, you can plainly see these changes in altitude. Earth becomes a boat bobbing in a sea with broad swells, and you can almost feel the pull of the centrifugal force of our planet's orbit (or at least your stomach turning over). Suddenly the seasonal changes take on a dynamical rather than leisurely quality. This is astronomy in action!

Of course, from behind a planetarium console, you're a minor deity dialing up twilight and stars. It needs but the twisting of a few controls to command a universe. Making the translation to the real sky, however, is not as straightforward. It takes a kind of rub-your-stomach/pat-your-head imagination.



For many people, the heavens will always be an abstract muddle. But if you're attuned to the rhythm of the sky, the daily motions of the Sun and Moon have a way of replaying themselves in the imagination day after day, year after year until one day, regarding the abbreviated shadows of mid summer or the dimming of the day in autumn you hear yourself say, "Hold on, I think I've seen this show before."

Then you begin to think about how all the cogs fit together and you recognize that it's not difficult to understand, really, if you just keep in mind that it's Earth that moves, not the Sun, and that because we're tilted slightly with respect to the plane of the solar system, we see the Sun bob up and down in our sky as we go around it.

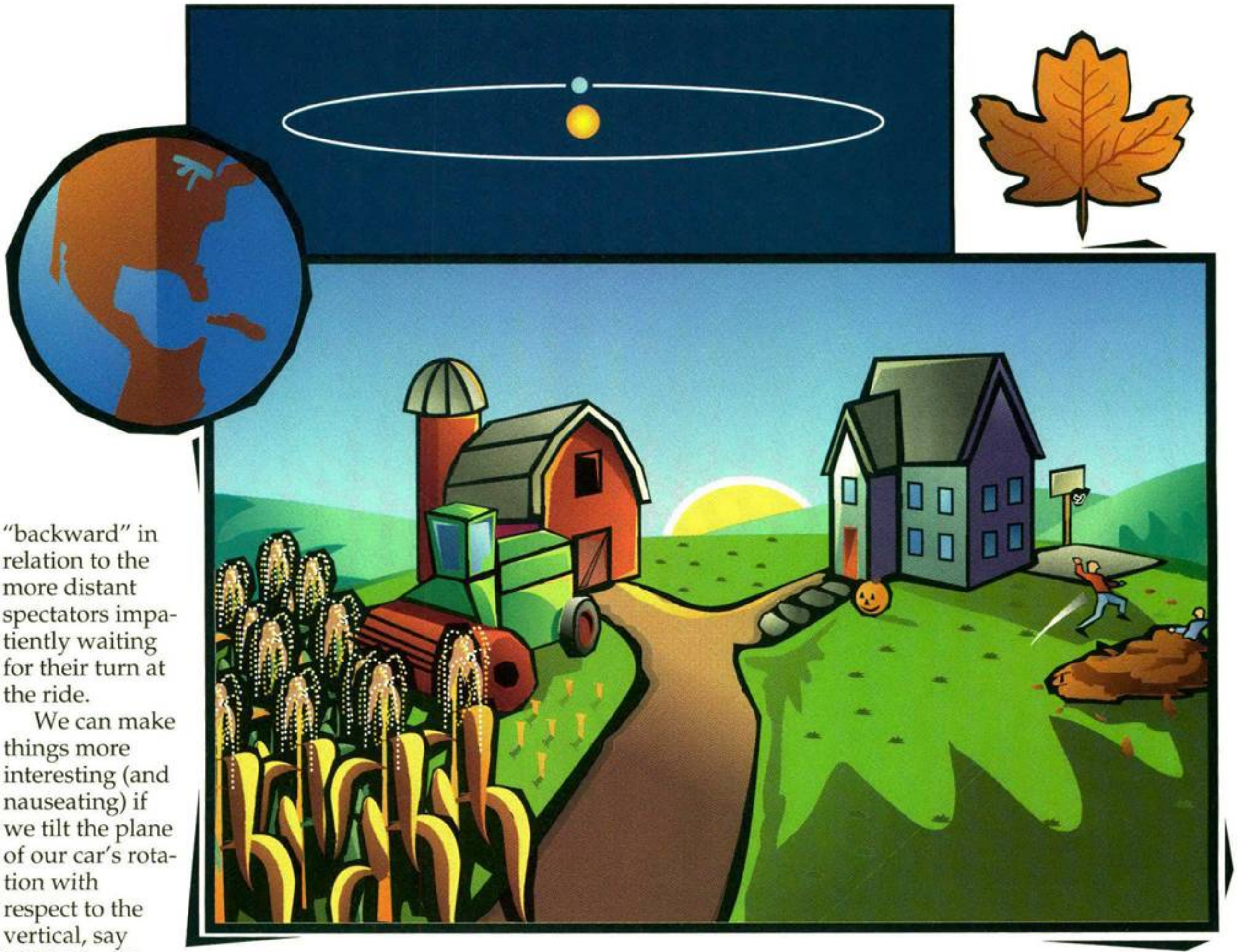
Consider one of the fundamental clockwork motions in the solar system, the Earth's orbit around the Sun. It takes 365.24 days to complete one orbit. As seen from the Sun, Earth moves ever eastward along its orbital path, the ecliptic, (or counterclockwise around the Sun as seen from the north pole of the ecliptic). From Earth each day we see the Sun shift a little less than 1° eastward along the ecliptic relative to the background stars. This subtle motion, however, is superimposed on the not-at-all subtle effect of our rotating planet, which makes the Sun appear to rise in the east and set in the west in a span of a few to many hours, depending on latitude and time of year. We see the Sun moving westward across the sky and call one complete cycle of this motion a "day."

On a day-to-day basis, of course, we tend not to notice the Sun's slight eastward motion because the background stars, which give us a frame of reference for the motions of the Moon and planets, are washed out by sunlight. Just as overlooked is the fact that Earth's rotational axis is kicked over 23.5° from the straight up position (never mind about where straight up is!). This makes the Sun appear higher in the sky for half of the year and lower in the sky for the other half.

But it's not in our nature to notice the little things until they add up to big things, which they inevitably do. Thus, one afternoon in March, preoccupied with your daily routine, you suddenly notice the Sun on your face and spy tiny buds sprouting on the elm trees. That little quickening in your chest is a physiological affirmation of the season's change and the recognition, albeit unconscious, that Earth is, after all, hurtling through space.

The whole business is easier to visualize if you picture yourself in the seat of one of those amusement park rides often called a Tilt-a-Whirl. This ride rapidly spins your car while also moving you and the other cars around a central hub of colorful carnival lights. For the sake of making this analogy relevant to Earth, let's imagine that each car spins counterclockwise while being conveyed around the hub in a counterclockwise direction. Now we have a close analogy to Earth (your spinning car), the Sun (the hub lights), and the direction of Earth's rotation and orbit about the Sun (counterclockwise, as seen from north of the ecliptic).

What do you observe? How does the gaily lit hub appear to move? As you spin, you see the hub lights appear to your left, move rapidly across your field of view, and disappear to your right (i.e., the rising and setting Sun). The overall counterclockwise direction of your whirling car makes the hub appear to move



"backward" in relation to the more distant spectators impatiently waiting for their turn at the ride.

We can make things more interesting (and nauseating) if we tilt the plane of our car's rotation with respect to the vertical, say 23.5°. Now the hub — in addition to the motions already mentioned — will appear to rise and fall regularly as the car tilts and whirls through its "orbit." At one point during each lap, the hub will reach its lowest altitude in our rider's field of view — below his equatorial "nose" — while during the second half of the lap it will reach its most elevated position, forcing our rider to lift his eyes slightly to center the hub in his sights. (Warning! Don't try this experiment after consuming a chili dog, candy apple, and big orange drink.)

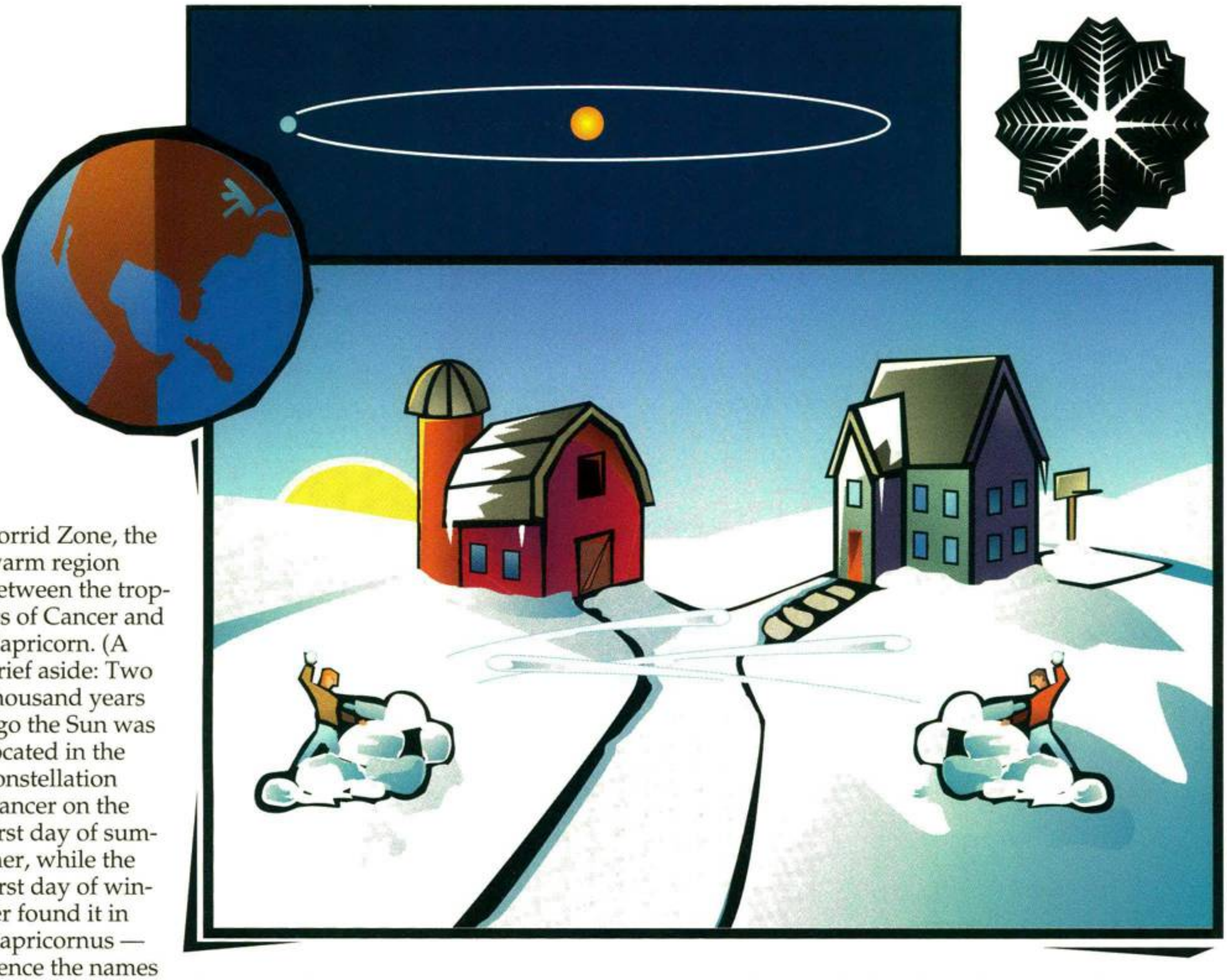
The Tilt-a-Whirl schematic is analogous to what's happening as Earth goes round the Sun. For six months out of the year an observer at a particular latitude is inclined more or less directly toward the Sun, so the Sun is high in the sky, while for the other six months one is inclined more or less away from it, so the Sun is low. From the observer's perspective, the Sun shifts north or south throughout the year with respect to the celestial equator (the plane of Earth's equator projected into space). The amount the Sun moves north or south in a day is not quite as great as its motion west to east, but the motion is fastest around the time of the equinoxes, the instances when the Sun crosses the celestial equator heading north (about March 21), called the vernal equinox, or south (about September 23), the autumnal equinox.

From the vernal equinox, the sunrise point at middle northern latitudes moves northward about a half degree per day. During both equinoxes, this motion is faster at the poles and slower at the equator.

From all locations in the Northern Hemisphere, the celestial equator arcs across the sky south of the zenith at an angular distance equivalent to one's latitude. For our mates in the Southern Hemisphere, it stretches north of the zenith, again by an amount equal to latitude.

Let's get specific. On March 20, 1996, at 3:03 a.m. EST, the Sun will be centered on the celestial equator, so it has a declination of 0° (declination is the angular distance above or below the celestial equator). On that day, observers standing on or around the equator will see the Sun overhead around noon. Observers located well north of the equator, say at latitude 33°N, will see the Sun 33° south of their zenith at local noon (or about 57° above their southern horizon). For those at latitude 40°N, the Sun would be 40° south of their zenith (or at an altitude of 50°). This relation can be applied to any location in the Northern Hemisphere. Essentially, your latitude equals the Sun's angular distance south of your zenith at local noon on the vernal or autumnal equinox.

Unless our celestial Tilt-a-Whirl comes to a screeching halt, the Sun will continue its northward trek until June 20/21, when it reaches its greatest distance north of the celestial equator, the summer solstice. On that day, the first day of summer in the Northern Hemisphere, the Sun is overhead at noon for people living at latitude 23.5° N, a demarcation known as the tropic of Cancer, and the northernmost boundary of the



ASTRONOMY/ Phil Kirchmeier

Torrid Zone, the warm region between the tropics of Cancer and Capricorn. (A brief aside: Two thousand years ago the Sun was located in the constellation Cancer on the first day of summer, while the first day of winter found it in Capricornus — hence the names tropic of Cancer and tropic of Capricorn.)

By the summer solstice, the Sun will have shifted northward by 23.5°. So if you live at latitude 33°N, the Sun will be 33° - 23.5°, or 9.5° south of your zenith on that day (or at an altitude of 80.5°). From latitude 40° N, it will be 16.5° south of the zenith (altitude 73.5°). The Sun goes no farther north (or south) of the celestial equator than 23.5°, because that's how far Earth's pole is tilted with respect to the ecliptic. The angle of this tilt between the ecliptic and the equator is called the obliquity of the ecliptic.

Now here's something really useful: The Sun is conveniently positioned over Earth's equator (0° latitude, 0° declination) at local apparent noon at the vernal equinox. This makes it easy to determine how the Sun will shine down on your part of the world at noon on the first day of summer. This comes in handy if you want to plant shade trees, build a patio roof, or install a swimming pool. The problem is estimating how much farther north 23.5° is in the sky from the Sun's current springtime position at noon.

If you have an equatorially mounted telescope, you can offset from the Sun using your setting circles and skip this paragraph entirely. If you don't have setting circles, or don't care to split tolerances down to the arcsecond, you can use your fist. You may have heard that the span of a fist when held at arm's length is roughly 10°. This is true if you have a typical fist. If you have the hands of a bricklayer, however, this measurement may be more like 14° or 15°. Calibrate your fist using the Big Dipper. The stars diagonally across from each other in the cup are a little over 10° apart, so if your extended fist eclipses both stars, your span is greater than this amount.

After you have correlated your fist size to the Dipper, you only have to subdivide your fist to make up the three and a half degrees. On a normal fist, this is about two fingers — the index and the middle. For larger hands, one and a half fingers or even a thumb may suffice.

Sight in the Sun, being careful not to stare directly at it, then mark off 23.5° to the north using your well-calibrated fist, and note the position. That's where the Sun will be the first day of summer, when it is highest in the sky and beating down unmercifully. Plan your porch roof and deck accordingly.

Without a doubt, some of the credit for the development of our species' imagination and sometimes-indomitable spirit must lie in the fact that Earth has tilted and whirled its way about the Sun throughout our evolution. It's a good thing we don't orbit in neat, boring little circles like a Merry-Go-Round. Where's the challenge and the joy in that? □

Jeff Kanipe (jkanipe@astronomy.com) is the managing editor of ASTRONOMY. Inspiration for this story came from his former job as the Tilt-a-Whirl operator at Slap Happy's Carnival and Amusement.

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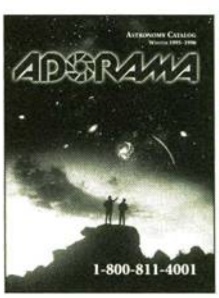

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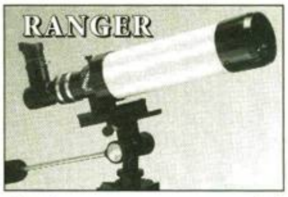

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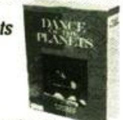

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SKY ALMANAC

Highlights
by Alister Ling

Date . . . .**Event**
14 The Moon and Jupiter at Dawn . . . . (p. 56)
20 Spot March's Young Moon . . . (p. 65)
22 Venus Shines. . . (p. 61)

all month:
Hale-Bopp Emerges into Morning . .(p. 61)
First Views:
Venus Shines . .(p. 61)
Observer's Challenge:
Two Springtime Obscurities . . . .(p. 63)
The Dance of Jupiter's Moons . . . .(p. 64)
Leo's Gathering of Asteroids . . . . .(p. 65)
Spot March's Young Moon . .(p. 65)

The Starry Sky:
Canes Venatici .(p. 62)

Venus dazzles evening skywatchers well beyond the end of twilight. To the south, a winding sea snake hands morning off to mighty Jupiter and a crescent Moon's gentle embrace.

by Deborah Byrd

As the sky begins to get dark this month, a bright "star" pops into view in the west. Some people will be tempted to make a wish on it. Others will gaze in its direction and remark to their companions, "Look, there's the evening star."

But this is no star. It's **Venus**, the brightest planet and next world inward from Earth toward the Sun.

Venus looks nothing like a star to practiced sky observers. At magnitude –4.3, the planet easily outshines everything else in the night sky, with the exception of our Moon.

At first you might think Venus looks so bright because it's close to Earth. In some ways, that is right. On March 1, it lies within eight light-minutes of Earth, in contrast to the 47 minutes light takes to come from vastly larger Jupiter, the second-brightest planet.

However, there's another reason why Venus shines with a brilliance so white. Clouds of sulfuric acid enshroud the planet and reflect almost 65 percent of the sunlight that strikes them. This, more than anything else, contributes to the planet's dazzling appearance in March's evening sky.

But blazing Venus is a sight to behold for another reason. At this time of year the ecliptic — the path along which the Sun, Moon, and planets seem to travel — takes on a steep angle to the western evening horizon.

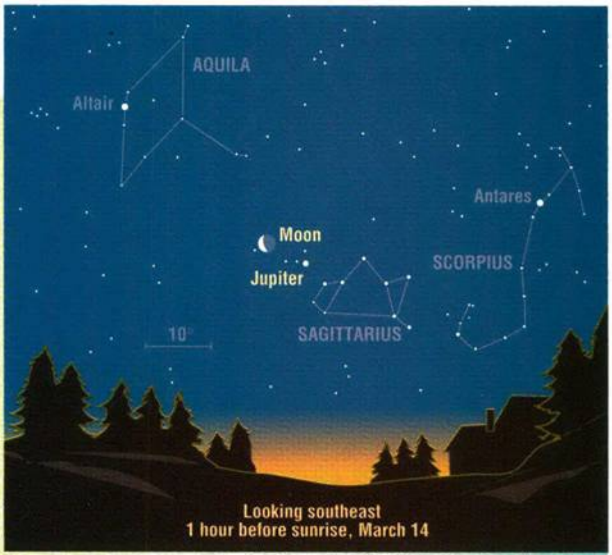
This translates Venus' angular distance from the Sun into a higher elevation above the western horizon. Indeed, as it approaches greatest elongation on March 31/April 1, when it lies farthest from the Sun for this apparition, the evening "star" sets a full 3½ hours after the Sun.

Such prominence in the west makes Venus a natural target for observers with telescopes. Throughout the month, the planet looks like a mini First Quarter Moon measuring about 20" in diameter. By the time Venus' evening apparition wraps up in June, its phase shrinks to a narrow crescent while its diameter swells to almost 58".

Venus begins March in front of the constellation Pisces, moving through Aries and into Taurus by the month's end. During the latter part of March, it lies near the Pleiades star cluster, also known as M45, the 45th entry in 18th-century comet hunter Charles Messier's catalog of deep-sky objects.

One particularly lovely sight happens on the

The Moon and Jupiter at Dawn



Looking southeast
1 hour before sunrise, March 14

The waning crescent Moon passes just north of Jupiter on the morning of March 14. Both are rather low in the southeast at the start of morning twilight because the ecliptic, the path followed by the Moon and Jupiter across our sky, makes a shallow angle to the eastern horizon.

While gazing upon this conjunction, bear in mind that Jupiter and its 16 moons are more than 2,000 times farther from us than the Moon.

Imagine if they were all only the Moon's distance away. Ganymede, the largest, would be 50 percent bigger and present a panorama of light and dark regions. The volcanic world Io, about our Moon's size, would be racked with eruptions in progress and lava lakes that grow and shrink nightly. Only Europa is smaller than our Moon, but since it is ice covered it would be five times brighter. Even the darkest Galilean moon, Callisto, is twice as bright as the Moon.

By far the strangest vista would be Jupiter. The mighty planet's 89,000-mile diameter would cover an astounding 20° of our sky. The Great Red Spot, a huge storm near Jupiter's equator, would have an apparent size of 2° by 5°. — *Alister Ling*

MARCH

4 Mars is in conjunction with the Sun, 9 a.m. EST

5 Full Moon is at 4:23 a.m. EST

8 Asteroid Massalia is at opposition (page 65)

12 Last Quarter Moon is at 12:15 p.m. EST

14 The Moon passes 5° north of Jupiter, 1 a.m. EST (page 56)
The Moon passes 5° north of Neptune, midnight EST

15 The Moon passes 6° north of Uranus, 11 a.m. EST

16 The Moon is at perigee (227,602 miles from Earth), 12:48 a.m. EST

17 Saturn is in conjunction with the Sun, 2 p.m. EST

19 New Moon is at 5:45 a.m. EST

20 Vernal equinox is at 3:03 a.m. EST

22 Mars passes 1.3° north of Saturn, 3 p.m. EST
The Moon passes 5° south of Venus, 7 p.m. EST

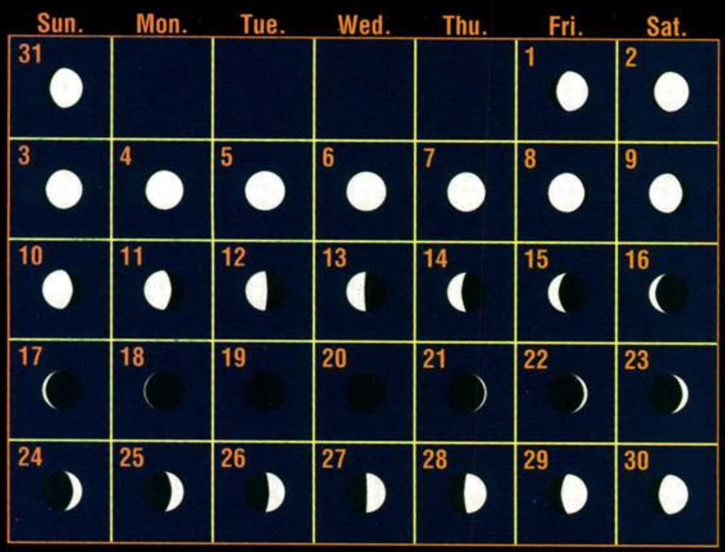
23 Mercury passes 0.3° north of Saturn, 6 a.m. EST
Mercury passes 0.9° south of Mars, 3 p.m. EST

26 First Quarter Moon is at 8:31 p.m. EST

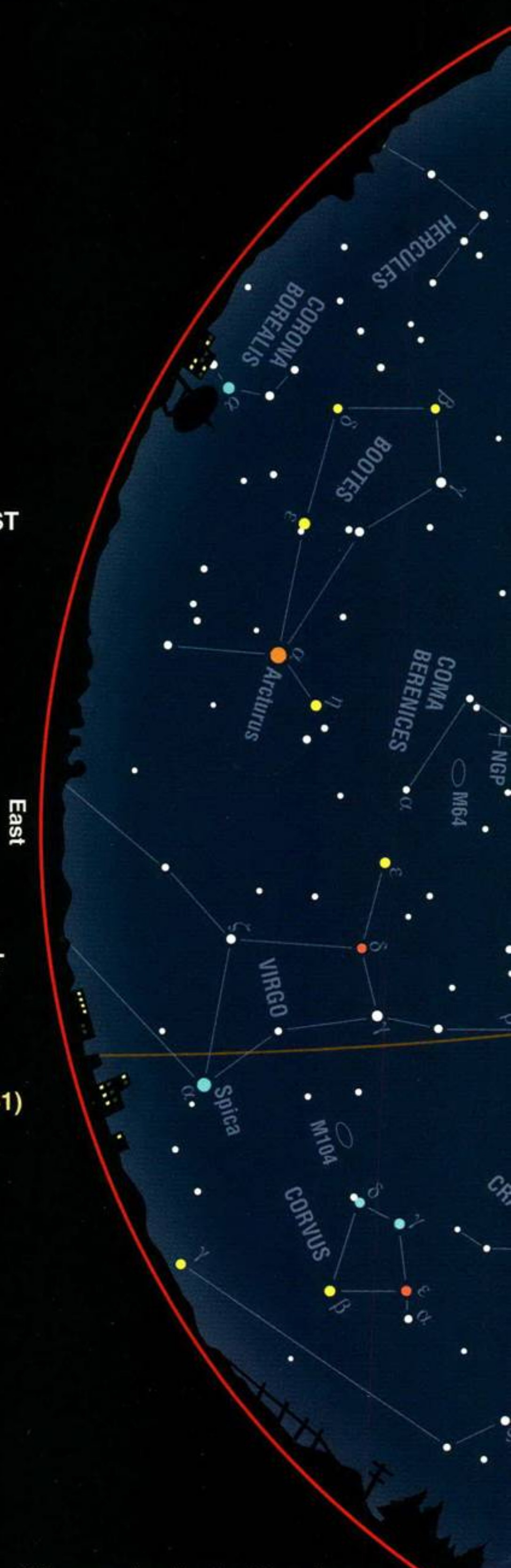
27 The Moon is at apogee (251,322 miles from Earth), 9:41 p.m. EST

28 Mercury is in superior conjunction, 3 a.m. EST

31 Asteroid Eunomia is at opposition
Venus is at greatest eastern elongation (46°), 8 p.m. EST (page 61)

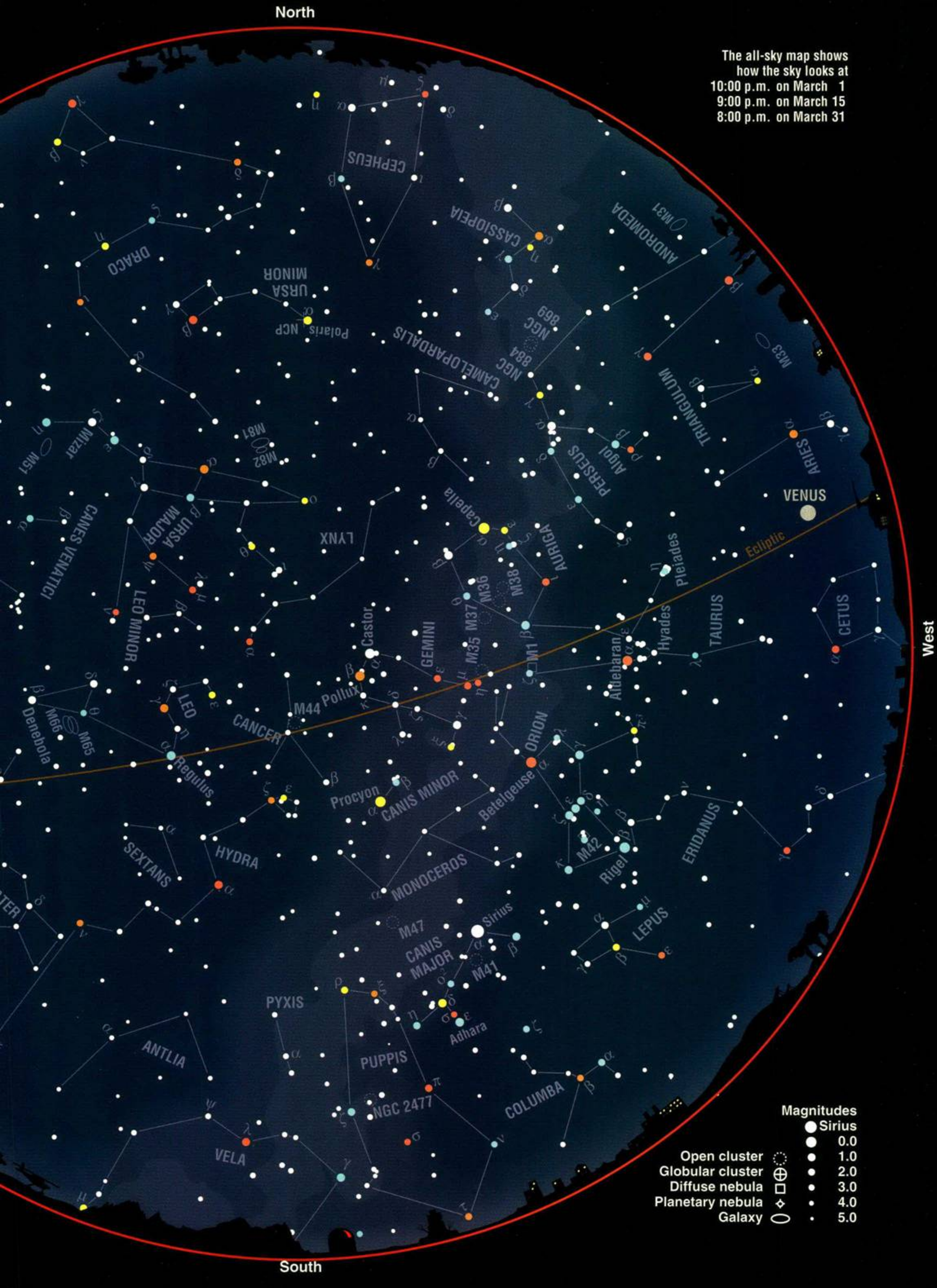


Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

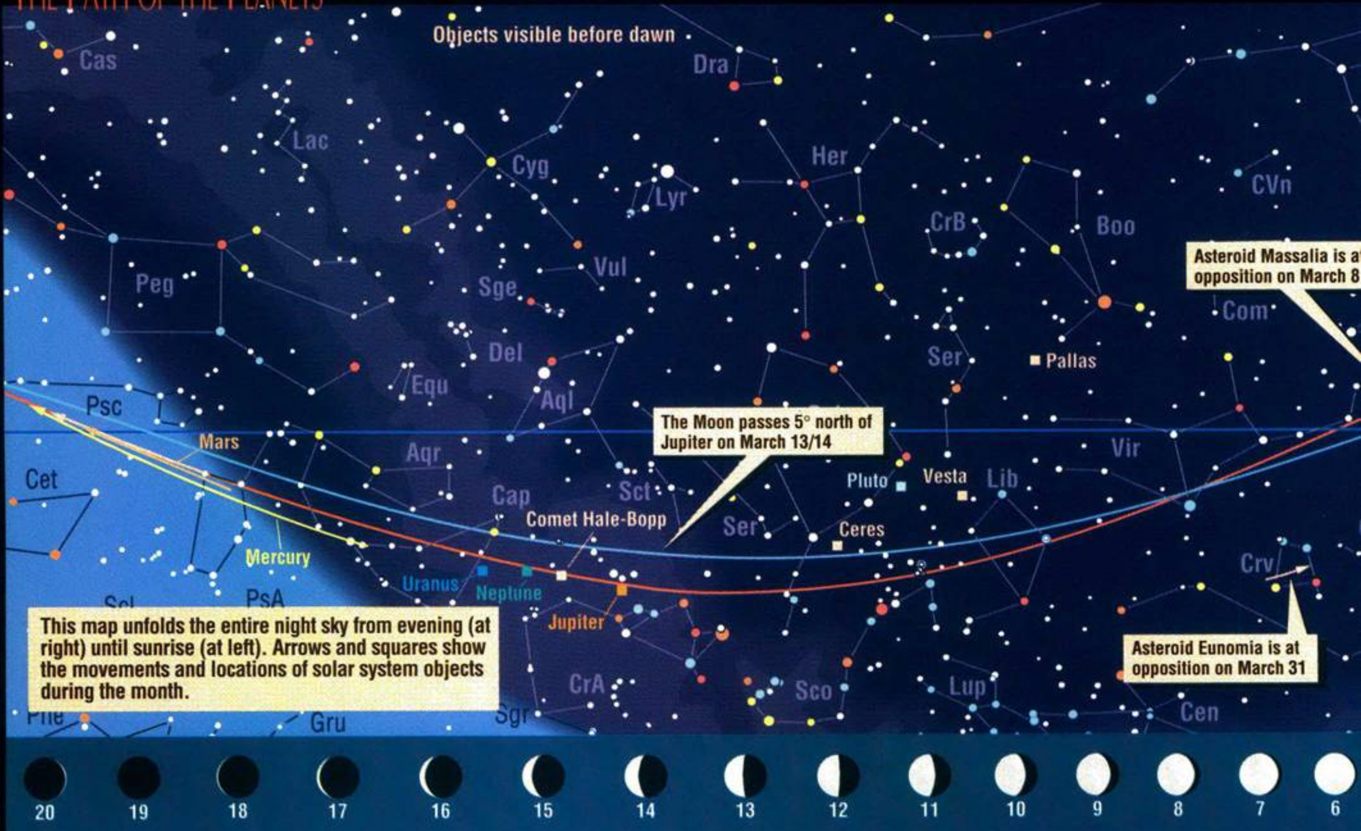


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows
how the sky looks at
10:00 p.m. on March 1
9:00 p.m. on March 15
8:00 p.m. on March 31


North
West
South
CEPHEUS
CASSIOPEIA
ANDROMEDA
M31
DRACO
URSA MINOR
Polaris NCP
CAMELOPARDALIS
NGC 869
NGC 884
M33
TRIANGULUM
ARIES
PERSEUS
Algol
M81
M82
M51
Mizar
URSA MAJOR
CANES VENATICI
LYNX
Capella
AURIGA
VENUS
Ecliptic
Pleiades
Hyades
TAURUS
Aldebaran
CETUS
M36
M38
M37
M35
M1
GEMINI
Castor
Pollux
LEO MINOR
LEO
M44
CANCER
M66
M65
Denebola
Regulus
Procyon
CANIS MINOR
Betelgeuse
ORION
M42
Rigel
ERIDANUS
SEXTANS
HYDRA
MONOCEROS
M47
Sirius
CANIS MAJOR
M41
LEPUS
PYXIS
Adhara
ANTLIA
PUPPIS
NGC 2477
COLUMBA
VELA
CRATER
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
Cas
Lac
Cyg
Lyr
Dra
Her
CrB
Boo
CVn
Peg
Sge
Vul
Com
Del
Equ
Aql
Ser
Pallas
Psc
Mars
Aqr
Vir
Cet
Cap
Sct
Pluto
Vesta
Lib
Comet Hale-Bopp
Ser
Ceres
Mercury
Crv
Uranus
Neptune
Scl
PsA
Jupiter
CrA
Sco
Lup
Cen
Phe
Gru
Sgr
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19
18
17
16
15
14
13
12
11
10
9
8
7
6

The Moon passes 5° north of Jupiter on March 13/14

Asteroid Massalia is a opposition on March 8

Asteroid Eunomia is at opposition on March 31

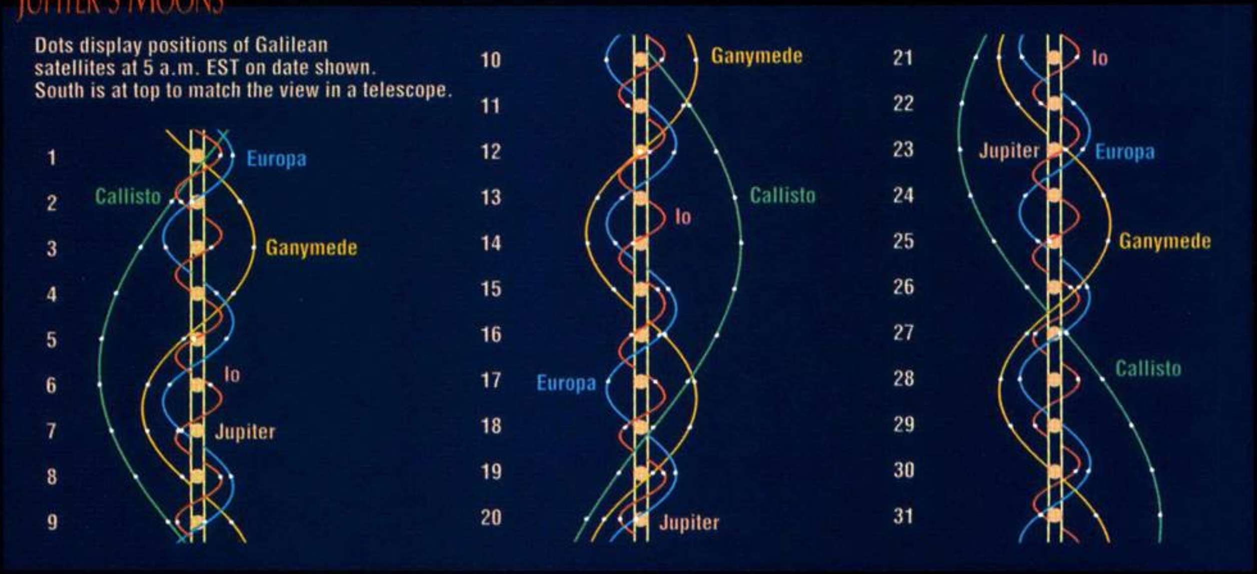
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

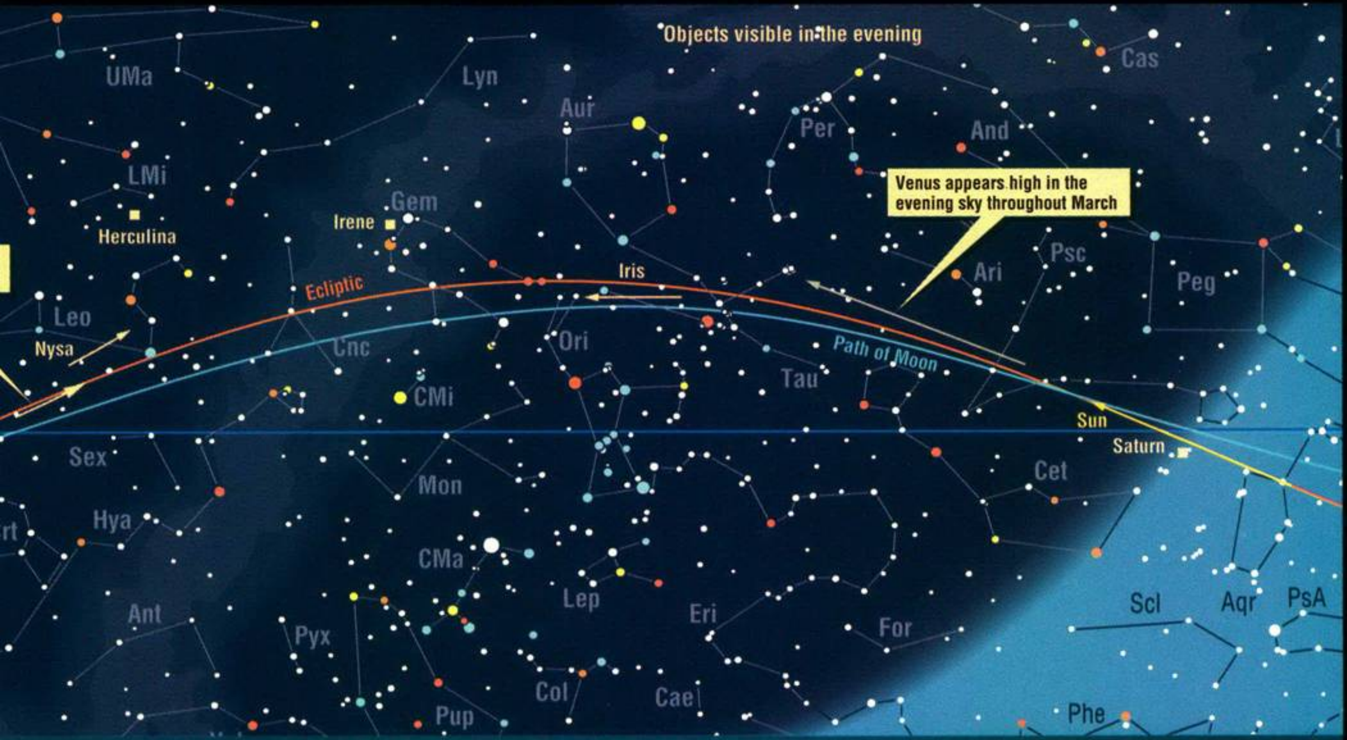
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

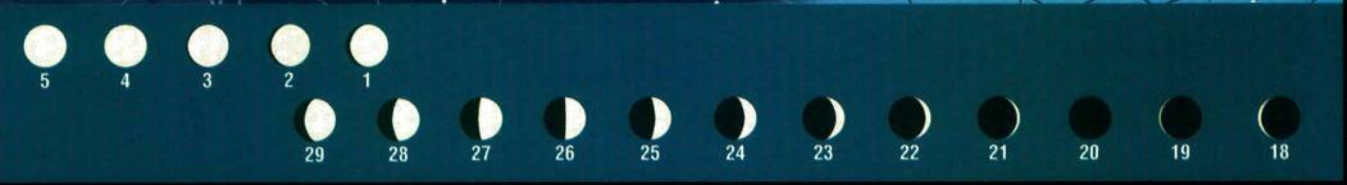
PLANETS	MERCURY	MERCURY	VENUS	MARS	JU
Date	March 1	March 15	March 15	March 15	M
Magnitude	–0.2	–0.7	–4.3	1.1	
Angular Size	5.5"	5.0"	19.9"	3.9"	
Illumination	82%	93%	60%	100%	
Distance (AU) from Earth	1.226	1.335	0.840	2.379	
Distance (AU) from Sun	0.464	0.420	0.719	1.385	
Right Ascension (2000.0)	21h31.8m	22h59.7m	2h27.3m	23h34.0m	19
Declination (2000.0)	–16°31'	–8°48'	16°37'	–3°49'	–

JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 a.m. EST on date shown. South is at top to match the view in a telescope.




Objects visible in the evening
Cas
UMa
Lyn
Aur
Per
And
LMi
Venus appears high in the evening sky throughout March
Herculina
Irene
Gem
Psc
Peg
Iris
Ari
Ecliptic
Leo
Nysa
Cnc
Ori
Path of Moon
Tau
CMi
Sun
Saturn
Sex
Mon
Cet
Hya
rt
CMa
Scl
Aqr
PsA
Ant
Lep
Eri
For
Pyx
Col
Cae
Pup
Phe


5
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28
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22
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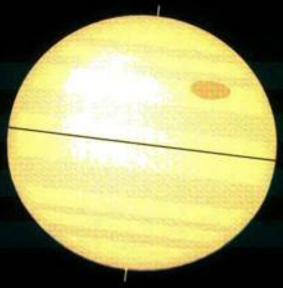
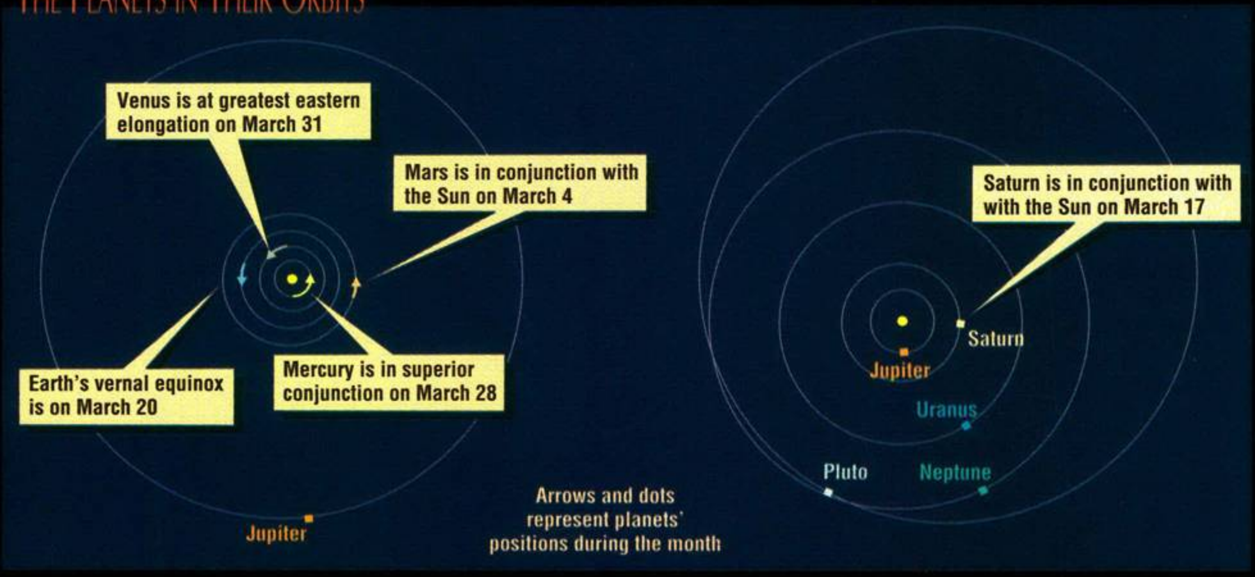
18



PITER	SATURN	URANUS	NEPTUNE	PLUTO
rch 15	March 15	March 15	March 15	March 15
–2.1	1.1	5.8	8.0	13.7
5.9"	15.8"	3.5"	2.2"	0.1"
99%	100%	100%	100%	100%
.486	10.549	20.363	30.686	29.519
.243	9.556	19.757	30.164	29.890
00.5m	23h52.9m	20h23.5m	19h56.8m	16h14.6m
2°34'	–2°58'	–19°55'	–20°14'	–7°45'

THE PLANETS IN THEIR ORBITS



Venus is at greatest eastern elongation on March 31

Mars is in conjunction with the Sun on March 4

Earth's vernal equinox is on March 20

Mercury is in superior conjunction on March 28

Saturn is in conjunction with with the Sun on March 17

Saturn
Jupiter
Uranus
Pluto
Neptune
Jupiter

Arrows and dots represent planets' positions during the month evening of March 22, when the young crescent Moon lies 5° south of Venus.

As Venus seemingly hovers above the western horizon all this month, the bright stars of winter shift deeper into evening twilight. They include Betelgeuse and Rigel in the constellation Orion, Aldebaran in the constellation Taurus, Sirius in Canis Major, Procyon in Canis Minor, Capella in Auriga, and Castor and Pollux in Gemini. These are the stars and constellations we typically associate with colder weather. And every March they unfailingly take leave of the evening sky as spring brings the promise of warmer nights.

Shortly before twilight yields to the dome of night, look northeast for the most familiar of all star patterns, the Big Dipper. The stars of the Big Dipper do not form an entire constellation. They form an asterism — a recognizable pattern of stars — in the constellation Ursa Major the Greater Bear.

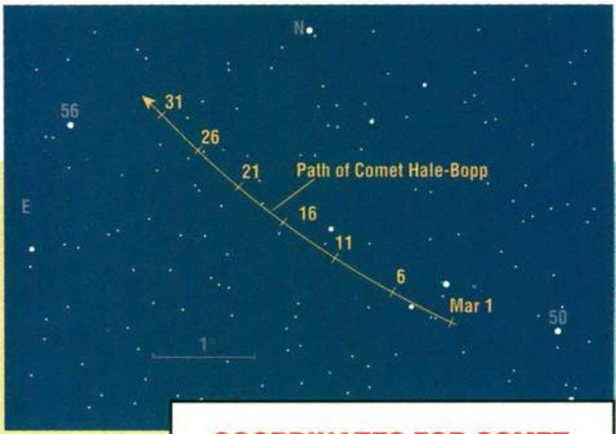
For those in the northern United States and Canada, this Northern Hemisphere icon is "circumpolar," which means it never sets and is always visible in the vicinity of the sky's north pole.

From the southern U.S., however, the Big Dipper dips below the horizon on winter evenings. But with spring, the Greater Bear and its Big Dipper amble back into their rightful position high in the north.

Seven stars make up the Dipper pattern, four in the bowl and three in the handle. Dubhe (α Ursae Majoris) and Merak (β UMa) are the bowl's two outer stars. They are sometimes called The Pointers, for an imaginary line drawn through them points to Polaris, the Pole Star.

Phecda (γ UMa) and Megrez (δ UMa) are the remaining bowl stars, and Alioth (ε UMa), Mizar (ζ UMa), and Alkaid (η UMa) form the Dipper's handle. Be sure to take a careful look at Mizar; another fainter star, called Alcor, appears

Hale-Bopp Emerges into Morning



This time next year, if predictions hold, Comet Hale-Bopp should be strutting its stuff as the brightest comet in 20 years. This month, however, Hale-Bopp's a magnitude-8.6 patch of light about ten times fainter than what the unaided eye can detect, inching its way through eastern Sagittarius. The comet lies east of the Teapot asterism, an area of the sky about 20° above the southeastern horizon as morning twilight starts.

Star hop to Hale-Bopp's area by moving three times the length of the Teaspoon's ladle. Consult the finder map or use the position table to plot Hale-Bopp's position on page 342 of the *Uranometria 2000.0* star atlas.

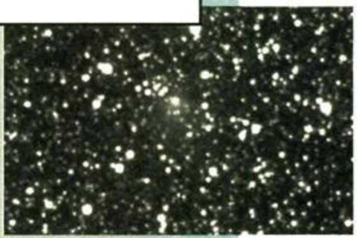
All during March, Hale-Bopp moves a little less than 1° each week. Between March 1 and March 6 it brushes a pair of 9th-magnitude stars and an 8th-magnitude star. That week also sees a gibbous Moon climb higher in the west each morning as darkness ends. Moonlight will be problem until March 16, when the waning crescent rises as dawn begins.

With the Moon out the way, late March also offers an opportunity to observe all of the Messier objects in one night. Messier marathoners can wrap up their object quest by bagging Hale-Bopp just before dawn, along with M55 and M75. — *A. L.*

COORDINATES FOR COMET HALE-BOPP*

Date	R.A. (2000)	Dec.
March 1	19h30.6m	–21°43'
March 6	19h33.1m	–21°23'
March 11	19h35.4m	–21°04'
March 16	19h37.6m	–20°43'
March 21	19h39.5m	–20°23'
March 26	19h41.2m	–20°02'
March 31	19h42.6m	–19°40'

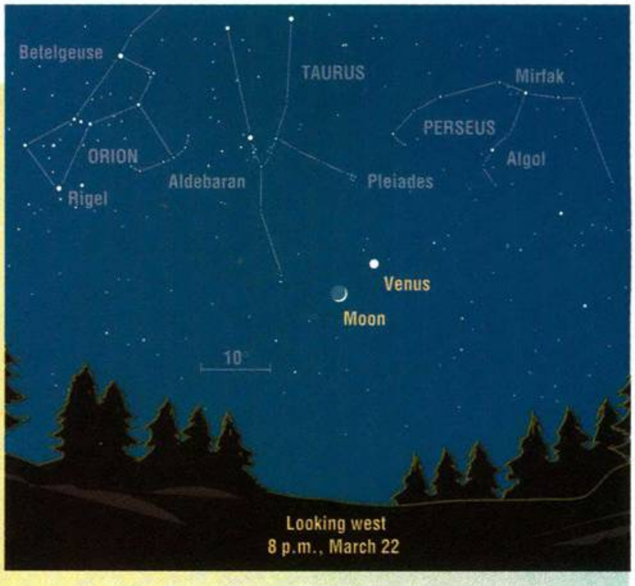
*Positions for 5 a.m. EST



Pedro Ré

First Views:

Venus Shines



Looking west
8 p.m., March 22

Have you ever wondered why Venus never joins Saturn or Jupiter in the late night sky? The answer is that because it orbits closer to the Sun, Venus can never venture far from the Sun in our sky.

A baseball analogy might help you picture the circumstances. Think of Venus as a short, infield fly ball. From Earth's outfielder point of view, such hits never land behind because the batter (the Sun) lies toward the infield.

Like a pop fly hit by the Sun, Venus has spent winter climbing up into the evening sky. At greatest elongation on March 31, it just seems to hang in our sky like a hovering fly ball. Then in May it sinks back toward the Sun.

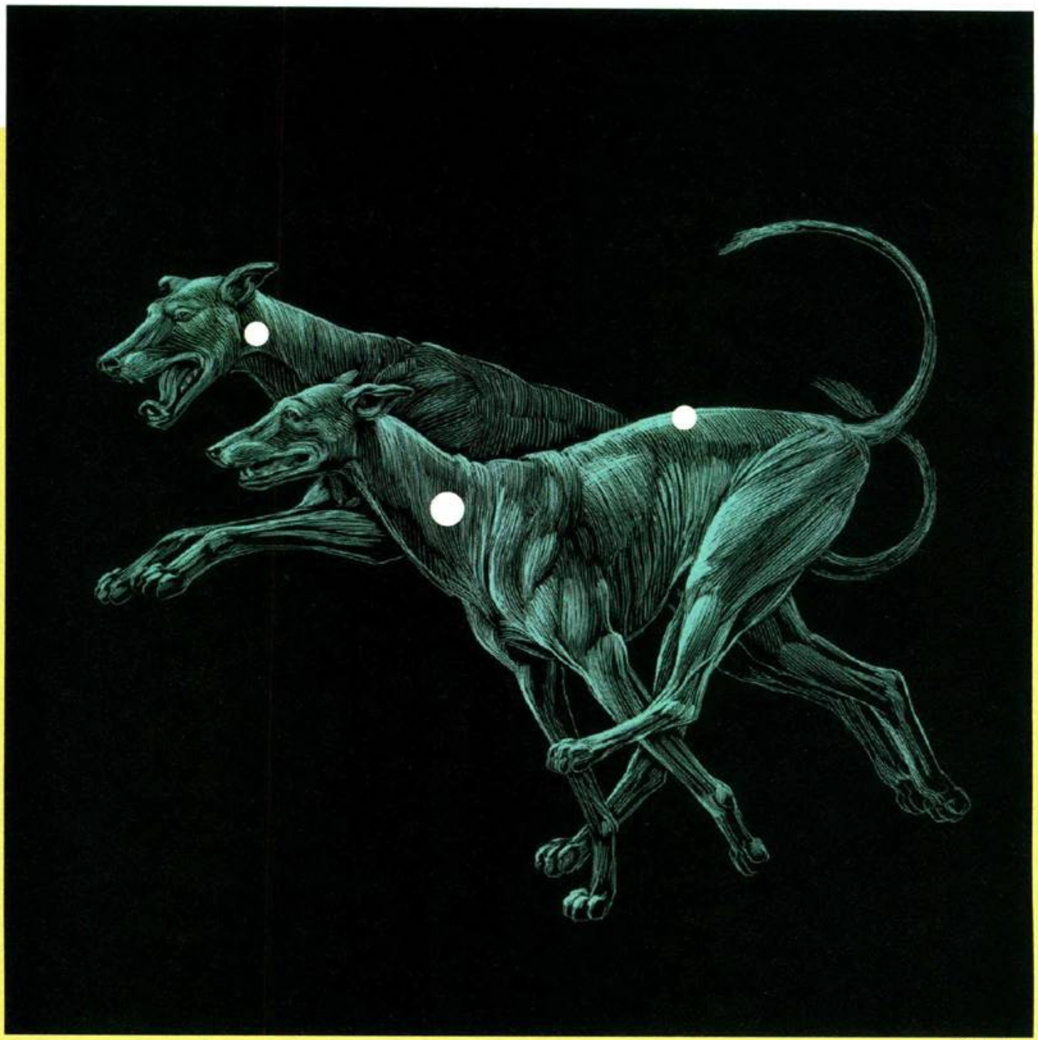
Reserve your box seats for the evening of March 22. That's when the Moon and Venus slide within 5° of one another. While in the area, check out the Pleiades and Hyades hanging above the pair like umpires. — *A. L.*

next to it. They are what's called an "optical double," two stars located next to each other along our line of sight.

Now shift your gaze to the eastern sky, where Leo the Lion ascends on these spring evenings. The head and shoulders of Leo consist of an asterism shaped like a backward question mark. This pattern of stars is sometimes called the Sickle. The brightest star in the Sickle is Regulus, whose name means "Little King."

Farther to the east, a triangle of stars defines the Lion's hindquarters. The triangle's brightest star has the name Denebola. Its root word "deneb" is in star names throughout the sky,

The Starry Sky: **Canes Venatici**



Keith Ward

At the end of evening twilight this month, while you are welcoming the Big Dipper back to the northeastern sky, look in that same direction for a constellation called Canes Venatici the Hunting Dogs.

People often confuse the Hunting Dogs with the Hunter's Dogs, the well-known Greater and Lesser Dogs that are the constellations of Canis Major and Canis Minor, respectively. Although the brightest stars in Canes Venatici aren't nearly as luminary as the anchor stars of Canis Major and Minor, this constellation is easy to find.

Canes Venatici lies just south of the Big Dipper's handle, in a location that harkens back to a time when Canes Venatici was considered part of Ursa Major. Its shape forms a line that connects the only two stars noticeable in this very tiny constellation.

The brighter of the two stars shines at 3rd magnitude and is called Cor Caroli, which means "heart of Charles." Popular folklore holds that Cor Caroli was named in honor of King Charles II of England by Edmund Halley. The star was said to shine with "special brilliance" on the evening of the King's return to London in May 1660. Scholars today assert that the star's original name was "Cor Caroli Regis Martyris," in honor of Charles I, who was executed many years earlier.

Cor Caroli attracts attention today as a popular double star for people with small telescopes. Its components, located about 120 light-years away, have magnitudes of 2.9 and 5.5 and are separated by 19". The two stars are a true binary star system separated from one another by 770 AU, almost 20 times Pluto's distance from our Sun.

In the constellation's scheme, Cor Caroli forms a collar for 4th-magnitude Chara, one of two hunting dogs that chase Ursa Major through the sky. The other dog, called Asterion, is represented by a line of 5th-magnitude stars that lie 5° to 10° east of Cor Caroli.

Another noteworthy star in Canes Venatici is located about 7° north of Cor Caroli. This is an orange-colored star called Y Canum Venaticorum, a variable star whose magnitude ranges between about 5 and 6.5. Astronomers calculate it to be one of the coolest stars known.

But the object that will bring you back to Canes Venatici again and again is not a star but a star island, a galaxy, consisting of billions of stars located some 35 million light-years beyond our Milky Way's boundaries. This is M51 or the Whirlpool Galaxy. You'll find this object easily with a small telescope about 3½° southwest of Alkaid, the end star of the Big Dipper's handle.

M51 was the 51st object French comet hunter Charles Messier added to his catalog of fuzzy, comet lookalikes, after he first glimpsed it in October of 1773. In the 19th century, it was the first deep-space object ever recognized to have a spiral shape, hence its moniker the Whirlpool Galaxy. — *Deborah Byrd* and in every case the name means "tail." In Leo's case, Denebola means "tail of the Lion."

South of Leo is another favorite target for spring constellation watchers. It's Hydra the Water Snake, a string of mostly 3rd- and 4th-magnitude stars that faintly winds its way above the southern horizon.

Whatever Hydra lacks in conspicuousness, however, it makes up for in size as the sky's longest constellation. The constellation stretches across almost one-third the entire sky's length, wiggling a path that begins under Cancer and continues underneath Leo, Crater, and Corvus before ending up near Libra. Alphard, Hydra's brightest star that marks the water snake's head, resides under Cancer.

A number of morning planets greet those who stay up late or get up early to see the entire length of Hydra.

Ambitious observers might hunt for magnitude-13.7 **Pluto**, which rises shortly after midnight.

This outermost planet, a thousand times too faint to be seen with the naked eye, lies in the constellation Ophiuchus. After March 7, Pluto begins a slow crawl westward in front of the stars. This "backward" or retrograde motion happens every year as Earth prepares to sweep between Pluto and the Sun.

At the other end of the visibility scale and rising around 3 a.m. is **Jupiter**, certainly a far easier planetary target than Pluto. The mighty planet brightens to magnitude –2.1 this month, making it the second-brightest planet after Venus.

Brilliant Jupiter is easily the most conspicuous morning sky object, even though the narrow angle its region of the ecliptic makes with the eastern predawn horizon keeps the planet rather low in our sky.

A waning Moon competes for attention on the mornings of March 13 and 14, when it draws close to

Observer's Challenge:
Two Springtime Obscurities

Mace Hooley

For a change of pace, this month's observer's challenge offers up two deep-sky objects. One of them, Upgren 1, is a star cluster easy to spot but often ignored because of its obscure listing. The other, Leo I, a well-known member of our Local Group of galaxies, is in an obvious location yet has a very low surface brightness, which makes it extremely challenging to detect.

The first target, Upgren 1, is readily visible in 7x50 binoculars. To find this Rodney Dangerfield of star clusters, center the bright stars of Canes Venatici, Cor Caroli (α CVn) and Chara (β CVn), in a binocular field of view. Then drop south to an area that forms an equilateral triangle with the two stars. Upgren 1 should be in the same field of view, a clump of about 10 to 15 magnitude 10 and 11 stars arranged in a field about 15' across, anchored by three members that shine at 8th magnitude.

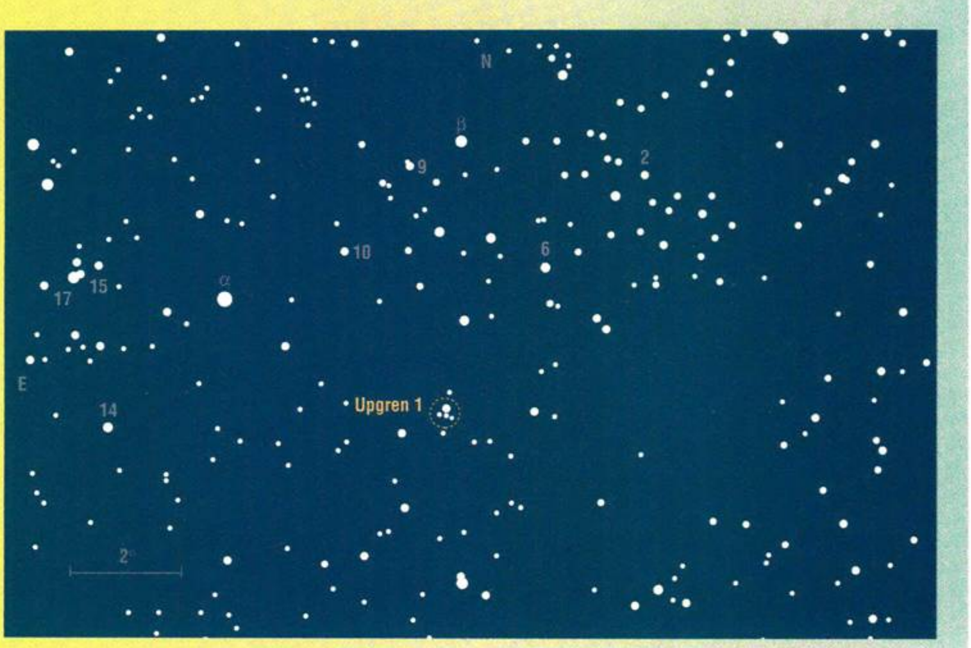
Through a telescope it's easy to see why Messier missed this one. It looks like a random clump of a few stars until you pan your scope to reveal there's nothing like it in brightness or density nearby. Upgren 1 is an easy way to begin an exploration of non-NGC star clusters using a comprehensive atlas like *Uranometria 2000.0.*

Our second challenging target lies only 20' — less than one Moon diameter — north and slightly west of bright Regulus (see photo). Leo I is so faint that only a handful of observers have laid claim to seeing it. The dwarf galaxy has a ghostly form barely brighter than the background sky, even in larger scopes like my 12.5-inch. Don't let a listed magnitude of 10.5 fool you; its brightness is spread over 12' by 9.3'.

Start your search for Leo I after 11 p.m., when its area of the sky is almost overhead. Double check that your scope's optics are free from light-scattering dew. Since Leo I is so faint and diffuse, approach it from the north to avoid the icy blue glare of Regulus.

After centering the scope on where Leo I ought to be, drape a dark hood over your head to prevent stray light from striking your eyes. Pause ten minutes to let them get dark adapted. Then slowly start sweeping the area at higher power, say 200x. Such a high magnification helps improve image contrast. Be patient. After a few minutes of slowly panning around, you should notice an increase in sky brightness in one spot that is shaped like an oval. That's Leo I. Confirm its presence by trying a variety of magnifications.

There have been documented sightings of Leo I in 10-inch telescopes. Theoretically at least, the dwarf galaxy should be visible in something as small as an 8-inch. For those of you who have access to really dark skies, how about a 6-inch refractor? Go for the gusto and send your results to ASTRONOMY's Reader Reports. —*A. L.*



The Dance of Jupiter's Moons

GALILEAN SATELLITE PHENOMENA

Date	Event	Time (EST)
	IO	
March 12	Shadow enters	2:28 a.m.
	Transit begins	3:39 a.m.
	Shadow leaves	4:41 a.m.
	Transit ends	5:53 a.m.
March 19	Shadow enters	4:22 a.m.
	Transit begins	5:35 a.m.
	Shadow leaves	6:35 a.m.
	Transit ends	7:49 a.m.
	EUROPA	
March 16	Shadow enters	3:27 a.m.
	Transit begins	5:52 a.m.
	Shadow leaves	6:10 a.m.
	Transit ends	8:37 a.m.
	GANYMEDE	
March 26	Shadow enters	2:15 a.m.
	Shadow leaves	5:08 a.m.
	Transit begins	7:21 a.m.
	Transit ends	10:22 a.m.
	CALLISTO	
March 26	Eclipse begins	4:45 a.m.
	Eclipse ends	6:11 a.m.

Jean Dragesco

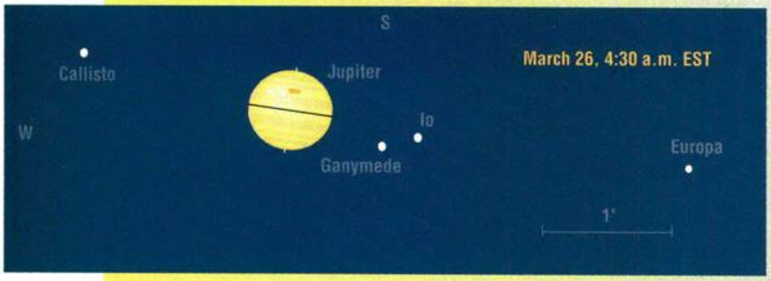
"It's got moons!" I remember shouting out loud the first time I saw the Galilean moons of Jupiter. I was even more astounded when the local astronomy club showed me that you can watch their shadows track across Jupiter's cloudtops as they move around Jupiter.

Humans have been observing these sights long before I discovered them in the 1950s. In 1675, the Dutch astronomer Ole Roemer was timing the moons and their shadows as they crossed Jupiter's face. Instead of the clockwork regularity expected of orbiting bodies, Roemer noted his timings lagged some 16 minutes behind predictions over the course of a year. He correctly figured this discrepancy came from the extra time it took light to travel from one side of Earth's orbit to the other. Working from this assumption, he calculated the speed of light to an accuracy of a few percent.

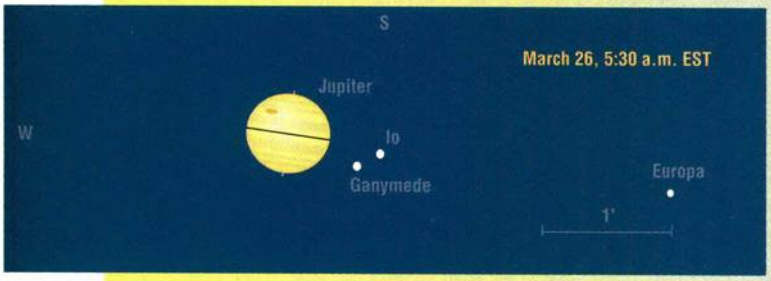
Today we enjoy the dance of Jupiter's moons for more aesthetic reasons. The accompanying table highlights some noteworthy events, such as transits, (when moons and their shadows cross Jupiter's face), occultations, (a moon passes behind Jupiter), and eclipses (Jupiter's shadow darkens a satellite).

One fine event occurs on the morning of March 19, when Io and its shadow drift across Jupiter's disk between 4:22 a.m. and 7:49 a.m. EST.

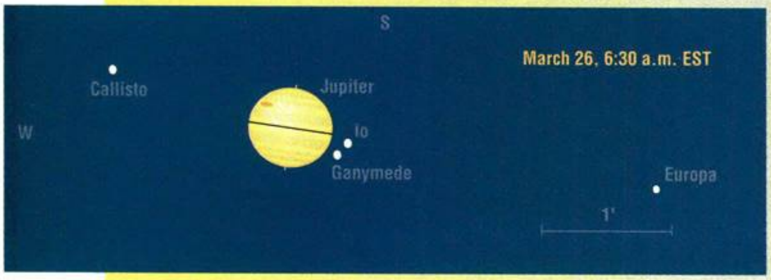
One week later, on March 26, we can watch Callisto pass into the planet's shadow at 4:45 a.m. EST and reappear more than an hour later at 6:11 a.m. EST (see diagrams). Note how Jupiter's rotation carries the Red Spot away from the planet's meridian. — *A. L.*



March 26, 4:30 a.m. EST



March 26, 5:30 a.m. EST



March 26, 6:30 a.m. EST

Jupiter (see "The Moon and Jupiter at Dawn").

If the early morning air seems steady enough, try looking through a telescope at Jupiter for evidence of its fast rotation rate. Because the planet takes only about 10 hours to spin around once and is composed mainly of gases, its equatorial diameter is slightly wider than its diameter through the poles.

This gives Jupiter a distinctly flattened appearance. In March, its apparent equatorial diameter measures close to 36", while the polar diameter is about 34".

After peering at Jupiter, pan your telescope or a pair of binoculars east to look for two other outer planets, **Neptune** and **Uranus**.

Magnitude 8.0 Neptune is in front of the constellation Sagittarius, while Uranus lies farther to the east and appears as a magnitude 5.8 point of light in Capricornus. Both planets are very low in the sky before dawn.

As you gaze at their faint light consider this: Two months ago astronomers on Palomar Mountain began searching 60 nearby stars for planets the size of Uranus and Neptune. The tug of invisible planets should show up as measurable variations in each star's position.

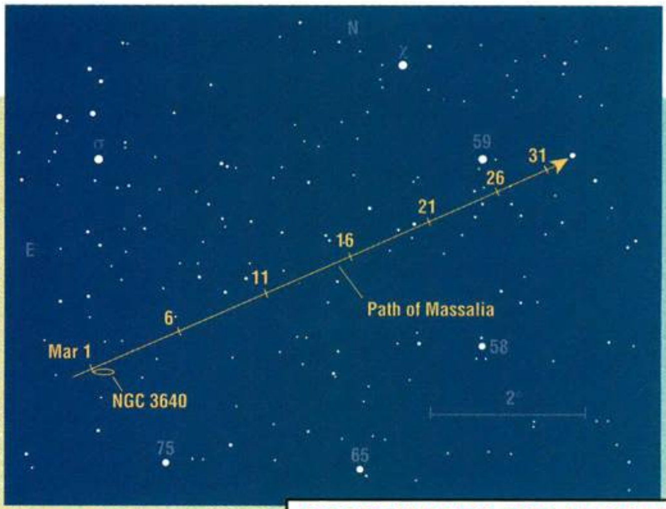
Rising later than Uranus and Neptune is **Mercury**, which gradually sinks deeper into the Sun's morning glare as the month progresses, headed for a March 28 pass behind the Sun.

Two other planets not visible this month are passing behind the Sun. **Mars** passes through conjunction on March 4, followed almost two weeks later by **Saturn**, which reaches conjunction on March 17.

Both creep into morning twilight next month, though Mars won't be easily visible until mid May. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Arizona.

Leo's Gathering of Asteroids



Three asteroids, one easy to follow through a telescope and two that are prime targets for CCD astrophotographers, sail through starfields of Leo this month. Massalia is an easy target in a 60mm refractor; Nysa and Unitas make better subjects for photography. 44 Nysa, which came to opposition on February 29, shines at magnitude 9.2, while 20 Massalia glows at magnitude 8.8 on its March 8 opposition date. Faint 306 Unitas, which came to opposition on February 29, glows at magnitude 12.4.

One way to hunt down these interlopers is by comparing starfield sketches or images made through a telescope days apart to see which "star" moves. Another is to wait for them to pass something interesting.

For the visual hunter, bright Massalia starts the month less than 3' northwest of the 10.3 magnitude elliptical galaxy NGC 3640 before heading northwest about 1 ° a week.

CCD imagers will have to subtract moonlight out of their pictures to capture Nysa and Unitas as they pass two bright spiral galaxies in Leo.

On March 5, Nysa lies 18', just over half a Moon diameter, to the south of 9.2 magnitude M96. The following evening it moves almost half way between M96 (10h 46.8m, 11° 49') and 9.7 magnitude M95 (10h 44.0m, 11° 42'). By March 7, it passes 7' northeast of M95. The daily double for M95 and M96 is Unitas, which moves two days ahead of Nysa along a very similar path. On the evening of March 2 magnitude 12.4 Unitas skims 9' southwest of M96, moving to 19' due west by March 3. — *A. L.*

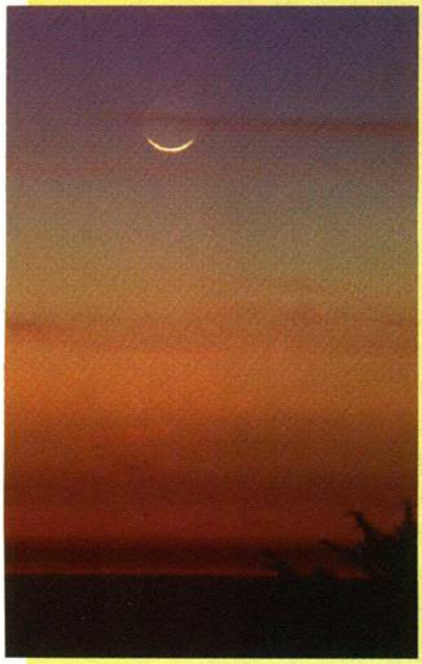
COORDINATES FOR MASSALIA*

Date	R.A. (2000)	Dec.
March 1	11h21.3m	3°16'
March 6	11h16.7m	3°47'
March 11	11h12.1m	4°18'
March 16	11h07.6m	4°48'
March 21	11h03.5m	5°17'
March 26	10h59.9m	5°42'
March 31	10h56.8m	6°03'

*Positions given for 11 p.m. EST

Spot March's Young Moon

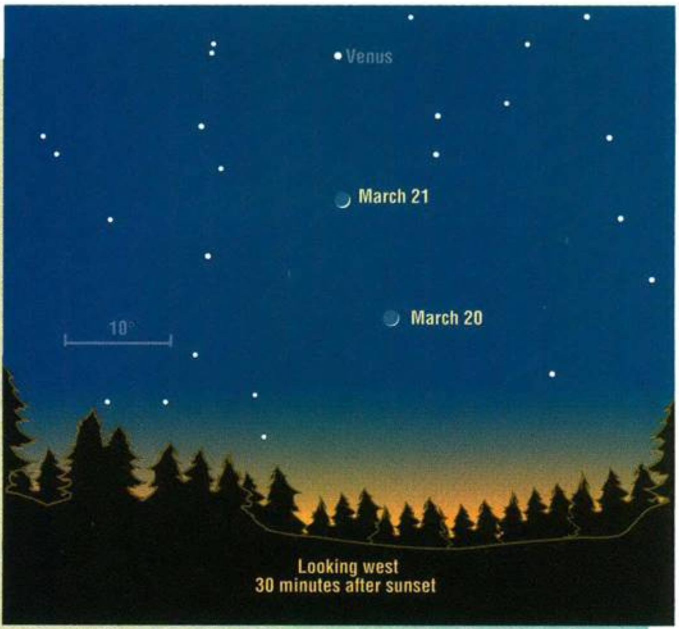
March is the month for young-Moon aficionados. This is because the ecliptic, the path our Sun and Moon appear to follow through the sky, makes a steep angle to the western horizon after sunset. Consequently, whatever separation the Moon has from the Sun translates into altitude above the western horizon. As a result, each spring during the months of March and April, young Moons strike dramatic poses high in the west after sunset.


L. H. Price

Many amateurs have made something of a sport out of spotting the youngest crescents soon after New Moon; the current record stands between 13 and 14 hours.

The best search strategy involves using binoculars to scan an uncluttered horizon directly above where sunset occurs. Using this technique, on March 19 observers in central North America have a shot at equaling the record.

Depending on their latitude, the Sun sets just 13 hours after New Moon, which occurs at 4:45 a.m. CST. West coast observers have a better chance at spotting the slim crescent, because the Moon will have aged another two hours by the time sunset happens for them.



On the next two evenings, March 20 and 21, the crescent becomes an easier target for observers everywhere. Looking for it directly below and slightly to the right of brilliant Venus. Don't forget to look for Earthshine, sunlight reflected from Earth's clouds and oceans onto the Moon's unlit portion. Can you see the Moon's gray, splotchy seas, or maria, in the reflected sunlight? — *A. L.*

Constellation Closeup

Remembering GEMINI

Two bright stars and a handful of fuzzy clusters and nebulae highlight one of the winter sky's most alluring figures.

by David J. Eicher

I remember the first time I got to know Gemini. It was a crisp, blustery, early spring night, and I stood beside an old 4¼-inch reflector at a friend's house in suburban Oxford, Ohio. Pinpoints peeked out over our heads in greater numbers through the deepening blue of the sky as the minutes passed. Two bright beacons took center stage as the friend wheeled the telescope toward Gemini's M35, a big, sprawling open star cluster. I peered into the eyepiece, gently pushed the telescope around for a minute, and finally asked what the little, faint cluster was beside the loose splash of stars comprising M35.

How the Twins Add Up

Gemini the Twins is a bright constellation, one of the most striking features of the winter sky. It is a so-called zodiacal constellation, meaning its stars lie along the ecliptic or zodiac, the apparent path of the stars and planets across the sky. Planets regularly pass through it. (In 1930, incidentally, Pluto was discovered while against the backdrop of Gemini.)

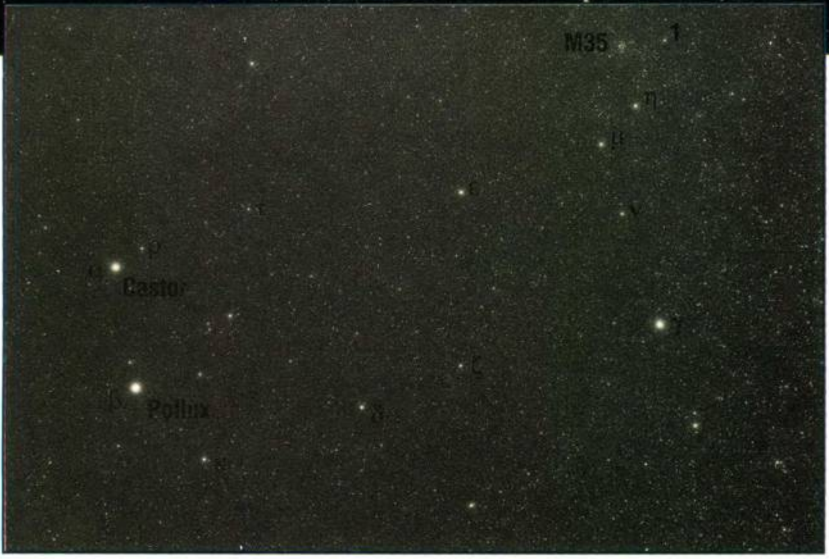
Covering 514 square degrees, Gemini is relatively large as constellations go. Its center lies approximately at 7h right ascension and 25° declination. Its brightest stars are 1st-magnitude Pollux (Beta [β] Geminorum), fainter Castor (Alpha [α] Gem), and 2nd-magnitude Alhena (Gamma [γ] Gem).

"It's NGC 2158," said the friend. "And it's similar to M35 but five times more distant." It was one of my first lessons in the surprising three-dimensionality of the sky. Around every predictable corner lies an unpredictable surprise. It's one of the things that makes amateur astronomy enriching — that keeps us going outside to look up at the stars when we could be inside, warm, and doing something more practical. Nowhere can we find a better reason to be outside than with Gemini.

Discover Gemini yourself on some evening this spring and you too will be caught by its charm. The constellation's rectangular form stands out on any clear night, dominated by bright stars Pollux (Beta [β] Geminorum) and Castor (Alpha [α] Gem), symbolizing the twins. These stars dazzle the eye: golden-yellow Pollux beams at magnitude 1.1 and stark-white Castor shines at magnitude 1.9. Though the two stars command the region as seen with the naked eye, other bright stars in Gemini form a pretty field for watching with eyes alone or with a simple pair of binoculars.

Walking around Gemini's boxy form in clockwise fashion brings into view Rho (ρ) Gem, Tau (τ) Gem, Mebsuta (Epsilon [ε] Gem), Mu (μ) Gem, Propus (Eta [η] Gem), Nu (ν) Gem, Alhena (Gamma [γ] Gem), Zeta (ζ) Gem, Wasat (Delta [δ] Gem), and Kappa (κ) Gem. Gemini the Twins is one of the constellations conceived in ancient mythological tradition (see box on p. 51).

Gemini's bright beacons form a sprinkling of relatively nearby stars ranging in distance from 35 light-years (Pollux) to 1,500 light-years (Zeta Gem). Beyond this framework of suns floating slowly around the Galaxy's center lies a network of more elusive game that requires binoculars or a small telescope to detect. The majority



Luke Dodd

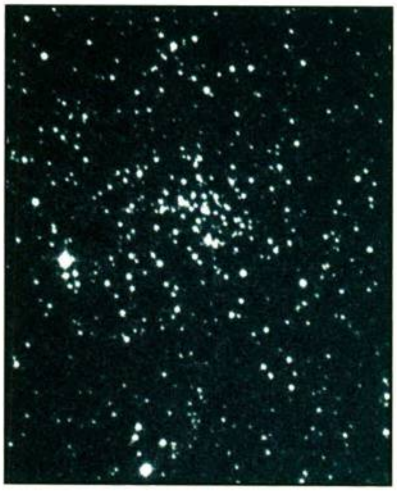
BRIGHT STARS CASTOR AND POLLUX dominate Gemini's rectangular form. The constellation holds sparkling double stars, the bright open star cluster M35, and a sprinkling of fainter clusters and nebulae.

of these deep-sky objects are open star clusters, the brightest of which is M35. Open clusters are young groups of stars that formed from collapsed pockets of dust and gas. M35 and even its little companion NGC 2158 can be glimpsed in binoculars. The

Open Clusters M35 and NGC 2158
Lee C. Coombs

Open Cluster NGC 2266
Preston S. Justis

Open Cluster NGC 2129
Bernard Abrams



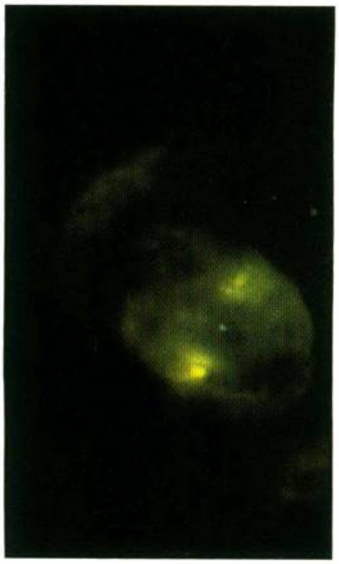
Open Cluster NGC 2355
Lee C. Coombs

Open Cluster NGC 2420
Martin C. Germano

Gemini's Treasures

Object	R.A.(2000.0)Dec.		Mag.	Size	Type
NGC 2129	6h01.0m	23°18'	6.7	7'	oc
NGC 2158	6h07.5m	24°06'	8.6	5'	oc
M35 (NGC 2168)	6h08.9m	24°20'	5.1	28'	oc
IC 443	6h16.9m	22°47'		50' by 40'	snr
NGC 2266	6h43.2m	26°58'	9.5_P	7'	oc
NGC 2355	7h16.9m	13°47'	9.7_P	9'	oc
NGC 2371/2	7h25.6m	29°29'	13.0_P	>55"	pn
PK 205+14.1	7h29.0m	13°15'	—	—	pn
NGC 2392	7h29.2m	20°55'	9.9	13"	pn
NGC 2395	7h27.1m	13°35'	8.0	12'	oc
Castor (α Gem)	7h34.6m	31°56'	1.9, 2.9	—	ds
NGC 2420	7h38.5m	21°34'	8.3	10'	oc

Along with the object's name, this table provides **right ascension** and **declination** in epoch 2000.0 coordinates, **V magnitude** (except when followed by a subscript P, which denotes a photographic magnitude), **size** in arcminutes, and **object type** (ds = double star; oc = open star cluster; pn = planetary nebula, and snr = supernova remnant).



Planetary Nebula NGC 2371/2
Bruce Balick, NOAO

cluster's 200 stars cover a disk of sky that appears nearly as large as that of the Full Moon, and it glows with the light of a 5th-magnitude star. The cluster can even be glimpsed with the naked eye on a dark night, though one must look carefully to separate it from the nearby row of three bright stars formed by Mu, Eta, and 1 Gem.

Other star clusters are dwarfed by M35's grandiose size and brightness, yet offer a challenge for observing with small telescopes from a suburban backyard. One of the prettiest clusters in the region, NGC 2129 may be found just 2° southwest of M35. It appears to contain a 7th-magnitude star, actually a foreground object aligned with the more distant cluster, near its center. Other clusters include NGC 2266, consisting of terribly faint stars, NGC 2355, NGC 2395, and NGC 2420.

Gemini holds another type of deep-sky wonder, planetary nebulae. These puffed-away shells from exhausted, aged stars represent a dying gasp at the end of a star's life. The Eskimo Nebula (NGC 2392) offers a treat for telescope users operating at high power. The nebula's tiny, blue-green disk lies encapsulated in a wispy fringe of light reminiscent in photos of a face in a parka, thus creating the nebula's sobriquet. Other fascinating planetaries are the larger, faint NGC 2371/2 and the extremely faint Medusa Nebula (PK 205+14.1), a challenge even for those who photograph deep-sky wonders.

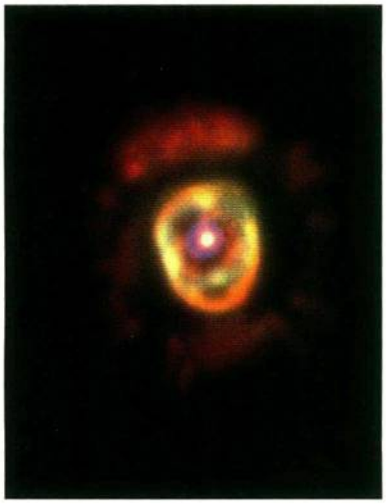
So much lies hidden in the vast spaces beyond the bright stars we take for granted every clear night of the year. Nowhere in the winter sky is this better illustrated than in Gemini, that ancient form that so forcefully continues to impart elegance into these spring evenings. From that single view of a glowing clump of stars in a 4¼-inch telescope, I came away with the aesthetic beauty of an entirely new place in the cosmos. In the end, after all, that's what observing the sky is all about. ☐

David J. Eicher is associate editor of ASTRONOMY. *His seven astronomy books include* The Universe from Your Backyard *(Cambridge University Press, New York, 1988).*

An Ancient Star Figure Lives On

Twin sons of the Greek mythological figures Leda and Zeus comprise the constellation figure of Gemini. The brothers, standing arm in arm, are among the oldest of all mythological figures imagined by humanity to exist in the sky. "The conception of a sky couple for these stars has been universal from remote antiquity," wrote Richard Hinckley Allen in his classic *Star Names and Their Meanings*, published in 1899.

The individual stories of the Twins have varied culture by culture, but each recognizes a similar form in this group of bright winter stars. Individually the bright beacons are known as Castor and Pollux, shining with a contrasting clean, dazzling white and a golden glow. In Roman legend the brothers were placed in the sky to honor their brotherly love demonstrated on Earth. Other storytellers identify the twins with Apollo and Hercules or Romulus and Remus. The brothers were perhaps most poignantly recalled by Alfred, Lord Tennyson, who wrote, "When the face of night is fair on the dewy downs / And the shining daffodil dies, and the Charioteer / And starry Gemini hang like glorious crowns / Over Orion's grave low down in the west."



The Eskimo Nebula
Bruce Balick/NOAO

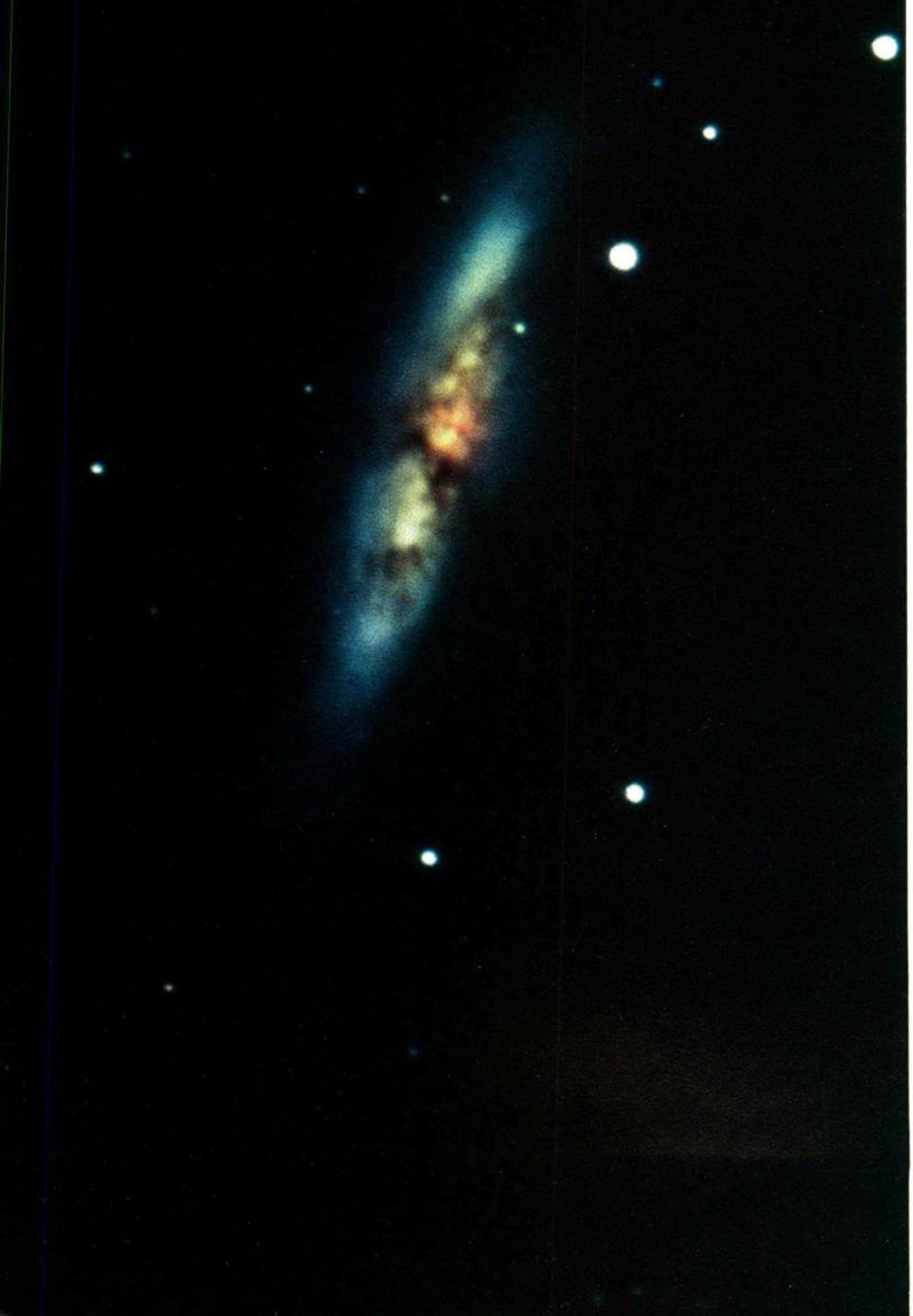
Supernova Remnant IC 443
Martin C. Germano

NGC 2395 (right) and PK 205+14.1
Martin C. Germano

Seeing the UNSEEN

With a medium-sized telescope and dark skies, you can perceive the outlines of cosmic dust in galaxies.

by Alan Goldstein



Peculiar Galaxy M82 in Ursa Major
by Jason Ware
(16-inch f/10 SCT, hypersensitized Fuji G800 film, composite of two 30-minute exposures)

Two kinds of matter make up the universe, the visible and the invisible. Normally, our telescopes live in the world of the bright stuff. We see the bright centers of galaxies, the wispy cocoons of glowing light that surround them. But with a little skill, patience, and dark skies, you can enter the world of the unseen.

Walking out under a very dark summer sky provides a glimpse of the unseen world. The glowing band of the Milky Way appears etched by a sinuous network of dark filaments and bands. These are rifts of dust in our galaxy made visible only because they are backlit by the soft glow of tens of thousands of stars.

Observing dusty galaxies takes seeing the unseen to a whole new level. In a single eyepiece view, it's possible to observe great swaths of dust light-years across along the edges of spiral galaxies, near the centers of anemic galaxies, or in the distorted forms of peculiar galaxies. The principle is the same: Again, the bright material composing the disks of these galaxies silhouettes the otherwise undetectable mass of dust grains from behind.

The Dry Dust of Galaxies

Galaxies consist of stars, dust, and gas. The stars provide most of the light that makes a galaxy visible. Much of the dust and gas present in galaxies forms in the atmospheres of first- or second-generation stars, and some of it from supernova explosions. All galaxies contain dust clouds. The sizes and arrangement of the clouds varies. Many spiral galaxies have dust lanes appearing to separate the bright parts of their spiral arms. These galaxies, like our own Milky Way, also have reservoirs of dust packed in their disks. The amount of dust varies from galaxy to galaxy.

Other types of galaxies contain even more dust relative to their masses. Irregular galaxies are disorganized clumps of stars, dust, and gas. The dust is not organized into belts or lanes but randomly distributed. Lenticular (lens-shaped) galaxies appear like a blend of spiral and elliptical galaxies, and they contain copious amounts of dust. Often these galaxies lie within large galaxy clusters, where they have been stripped of gas by colliding with other galaxies. Anemic galaxies are rich in dust and gas but abnormally low in luminous stars. Their spiral structure is often distinct. Perhaps the dustiest galaxies are those described as peculiar. They represent the galaxy freak show, many consisting of merged pairs of galaxies, exploded systems, or otherwise catastrophically disrupted galaxies. They are very dusty.

Distorted Barred Spiral NGC 2146 in Camelopardalis
by Rudolph Schild, Harvard-Smithsonian Center for Astrophysics

A Dusty Walk Through the Springtime Sky

Spring is the perfect season for spotting dusty galaxies. March evenings offer three distinct groups of dusty galaxies. The first, visible in the early evening, consists of objects in Andromeda, Cetus, and Camelopardalis. The second, visible in mid to late evening, contains galaxies in Ursa Major and Leo. The final group, viewable from late evening until after midnight, holds objects in Coma Berenices, Virgo, and Centaurus.

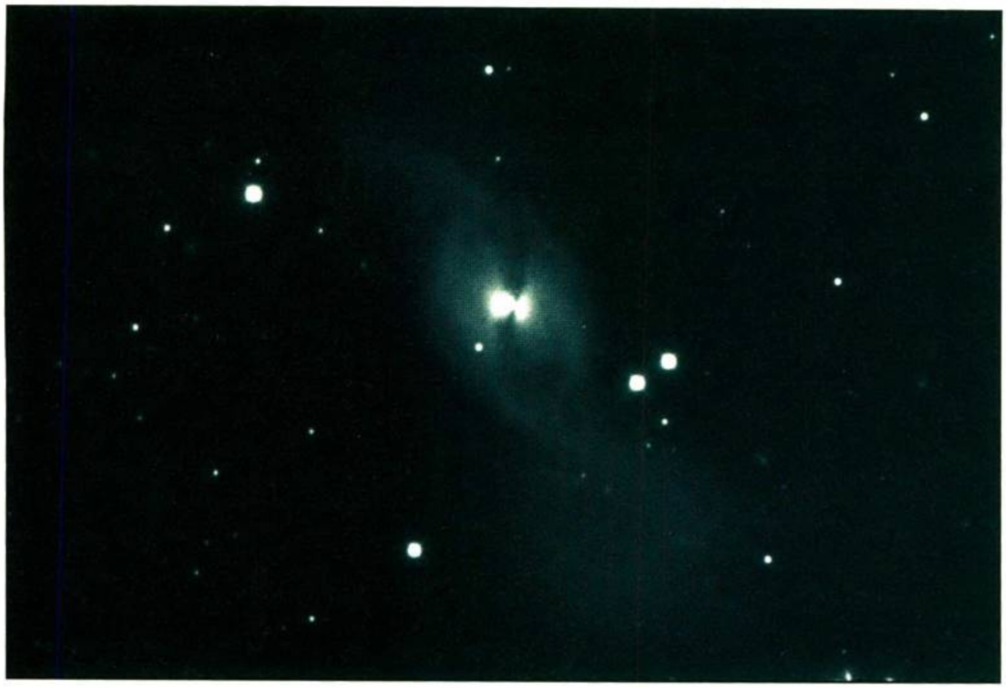
After dusk falls in the first days of March, train your telescope on the **Andromeda Galaxy** (M31, NGC 224). Our sister spiral in the Local Group of galaxies, the Andromeda Galaxy presents distinct dust lanes intermingled with its spiral arms. The lanes are visible in a 6-inch telescope on a dark night. The somewhat wispy dust lanes are best seen where they pass in front of (and slightly below) the central hub. As a challenge, try to detect the dust lanes on the galaxy's far side.

Also in Andromeda, **NGC 891** presents a challenge for small scope observers because of its ghostly, low surface brightness. Though the galaxy is an edge-on spindle, it glows with a total magnitude of just 10.0 spread over more than 13' of sky along its long axis. Thus, the dim, silvery light from NGC 891 eludes many a telescope. On a moonless night, however, a 6-inch scope reveals the galaxy's most distinct feature: a prominent lane of dust splitting its form cleanly into two halves. With a 10-inch or larger scope, the dust lane appears somewhat thicker near the galaxy's center. Because the galaxy lies oriented edge-on to

Spiral galaxy

A wheel of stars, gas, and dust with a large, flat disk component and spiral arms.

Cigar-Shaped Galaxy NGC 2685 in Ursa Major
Palomar Mountain Observatory



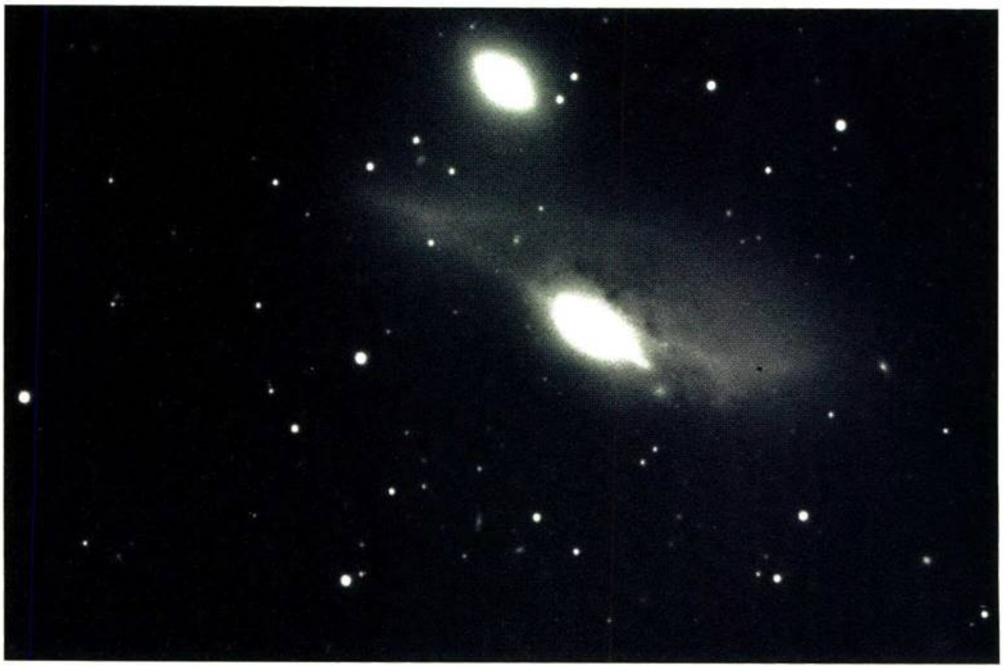
Peculiar Barred Spiral NGC 3718 in Ursa Major
by Kim Zussman
(14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 250-minute exposure)

Irregular galaxy

A patchy collection of stars and gas without regular shape or form.

our line of sight, immense clouds of dust are visibly projected in front of the galaxy's light. This, in part, gives NGC 891 its ethereal, dim glow.

Similar in shape to the Andromeda Galaxy but more distant, **NGC 253** in Sculptor also offers dust lanes defining its spiral arms. This galaxy remains hidden in the evening murk this time of year but several months from now will again present itself as a well-placed object. This disk-shaped galaxy makes an easy object for binoculars or finderscopes. An 8-inch scope reveals mottling in the galaxy's disk, indicating dust patches and star clouds.



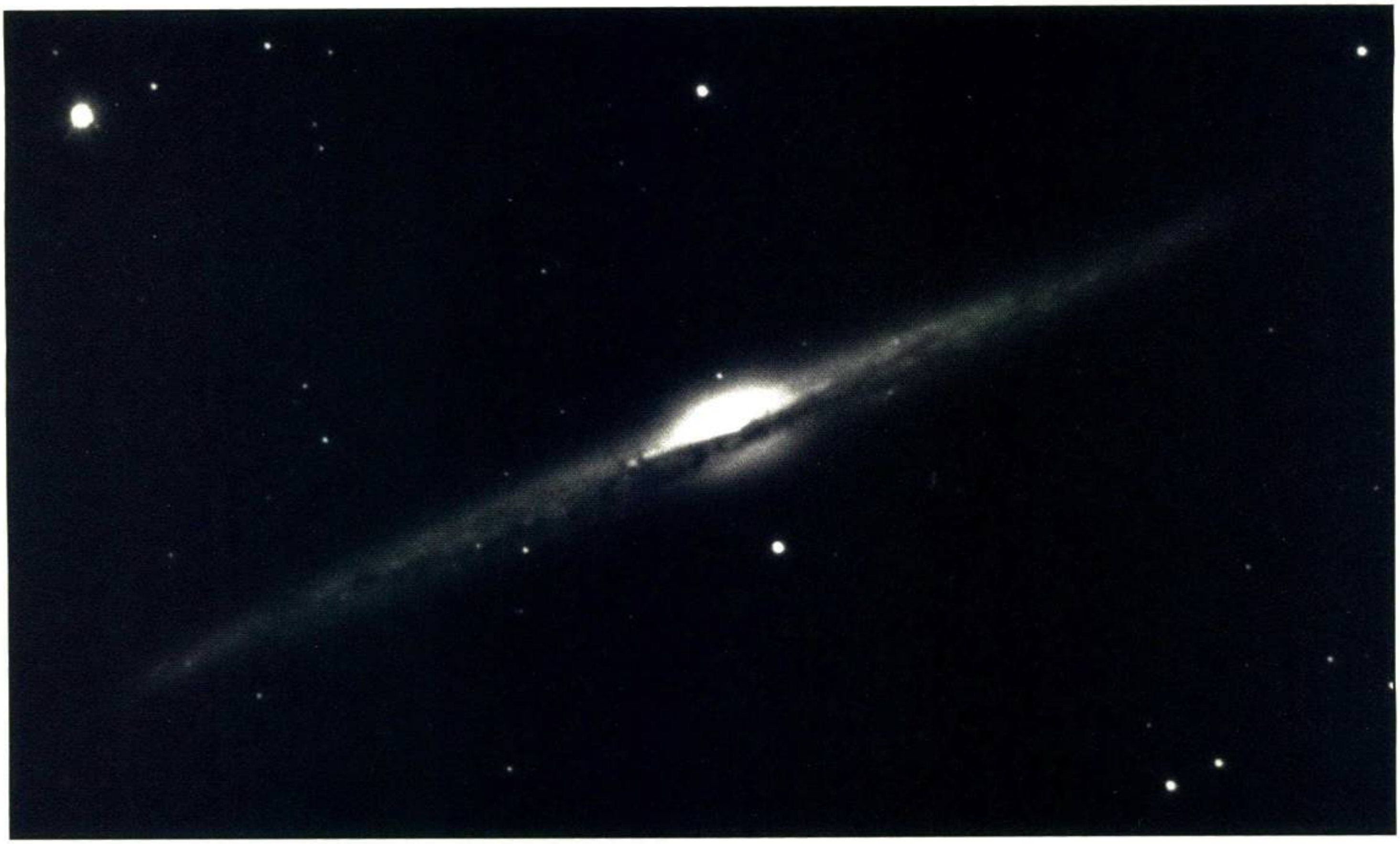
Interacting Galaxies NGC 4435 and NGC 4438 in Virgo
by Kim Zussman
(14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 151-minute exposure)

Still visible in the early evening is the diminutive galaxy **NGC 681** in Cetus. A disk-shaped spiral, this object resembles a distant version of the Sombrero Galaxy in Virgo (see below). Glowing faintly at magnitude 11.8, the object is a challenge to see at all in a 3-inch scope. A 10-inch instrument, on the other hand, shows the galaxy's prominent dark lane that bisects its disk. If this dusty detail seems stubborn, try observing it again on a night of exceptional transparency.

As a final early evening object, consider shifting your gaze toward **NGC 2146** in Camelopardalis. Long exposure photographs reveal a dusty, swirling mass in this magnitude 10.5, distorted galaxy. Dark tendrils of dust occult the galaxy's nucleus, and the whole mass is bowl-shaped, leaving an odd impression of the galaxy's apparently violent past. The distribution of dust across this galaxy makes observing it a real challenge for observers. Can amateur astronomers equipped with large scopes see this material?

A Dusty Walk Through Mid- to Late Evening

Two important areas of dusty galaxies mark the March sky as evening progresses. Now, at 9 p.m., it's time to cast attention toward the bright and attractive constellation Leo. There, edge-on spiral **NGC 3628** dominates the scene as dusty galaxies go. Gravitationally involved with the bright spirals M65 and M66, which are located in the same low-power field of view, NGC 3628 has a warped-dish shape that suggests interaction with the neighboring spirals. While this distortion is difficult to observe visually in M65 and M66, a good 8-inch scope at high power reveals the asymmetry in NGC 3628. The galaxy's prominent dust lane bisects the galaxy slightly on the diagonal, and the irregular thickness of the dust



Edge-on Spiral Galaxy NGC 4565 in Coma Berenices
by Chuck Vaughn
(12.5-inch f/9 Ritchey-Chretien, hypersensitized Tech Pan film, 90-minute exposure)

band stands out in telescopes 12 inches and larger.

Moving northward in the late evening sky brings into view the constellation Ursa Major and its Big Dipper asterism. One of the most prominent dusty galaxies, **M82** (NGC 3034), resides in northern Ursa Major. This magnitude 8.4 cigar-shaped galaxy appears to be mottled with dust as seen in telescopes as small as 8 inches. Observers with large telescopes can see an overwhelming amount of dusty detail set against the bright spike of light from the galaxy's disk.

Nearby lies the elliptical galaxy **NGC 3077**. Like M82, this object appears to be disrupted. Photos reveal intricate tendrils of dark nebulosity around the periphery of this galaxy's disk. Unlike dust in normal galaxies, the dust in NGC 3077 appears to entangle the bright parts of the galaxy from almost every angle. This is a challenging object: Can observers with large telescopes observe the dust in this galaxy?

Another Ursa Major oddball, **NGC 2685** consists of a spiral galaxy's disk with distorted peculiarities. The dark clouds of dust silhouetted against NGC 2685's center appear to cross the disk perpendicularly. Again, this is a real challenge for large backyard telescopes. Similarly, Ursa Major's **NGC 3718** offers a greatly distorted shape crisscrossed with dust. The galaxy appears to be interacting with nearby NGC 3729. A twisted filament of dark nebulosity arcs across NGC 3718's central hub. This lane is thinnest in the center and thickest at either end, making it a challenge to glimpse using large telescopes.

Lenticular galaxy

A lens-shaped galaxy that appears to have characteristics of both spiral and elliptical galaxies.

Elliptical galaxy

A spherical or elliptical cloud of stars, gas, and dust with a dense center.

A Dusty Walk Through the Late Evening Sky

After observing such delicate features in a multitude of galaxies in Ursa Major and Leo, it must surely be late evening by now. If so, try shifting your gaze to the constellations Coma Berenices, Virgo, and Centaurus, where you'll find still more dusty examples. **NGC 4565** in Coma Berenices is one of the most breathtaking galaxies in the sky, with its thin spindle-shaped structure bisected by a conspicuous equatorial dark lane. Unlike NGC 3628, this galaxy is symmetrical in both spiral structure and distribution of dust. The dust lane is visible in a 6-inch scope. Larger scopes reveal that the central hub

The Sombrero Galaxy (M104) in Virgo
by David Healy
(14-inch SCT at f/5.5, hypersensitized Fuji film, 30-minute exposure)

Anemic galaxy

A galaxy rich in luminous gas and dust but weakly populated with stars.

is not split evenly.

Also in Coma Berenices, the **Blackeye Galaxy** (M64, NGC 4826) offers one of the most widely observed dusty galaxy features. The dusty patch near the galaxy's nucleus that gives M64 its popular name stands out in a 6-inch telescope. Besides the dusty patch, however, little detail stands out from this galaxy.

Nearby Virgo contains two outstandingly dusty galaxies. **NGC 4438** is a distorted Sa peculiar galaxy similar in appearance to NGC 2146. This 10th-magnitude galaxy interacts with its slightly brighter elliptical neighbor, NGC 4435. Both lie near the core of the Virgo Cluster. NGC 4438's warped disk contains somewhat less dust than NGC 2146 and it requires a large telescope, a 16-inch or more, to pick out any patchy dust clouds. **NGC 4753** is another peculiar galaxy in Virgo. The dust is sufficiently thin to require large telescopes for a successful view.

Virgo's real treat, however, is the edge-on **Sombrero Galaxy** (M104, NGC 4594). This type Sb spiral is a massive galaxy much larger than the Milky Way. Large observatory telescopes show a swarm of globular clusters orbiting this "mega-spiral." Backyard scopes reveal a distinct dark lane crossing slightly off-center from the galaxy's hub. The nucleus may be glimpsed as a bright knot above the dark lane.

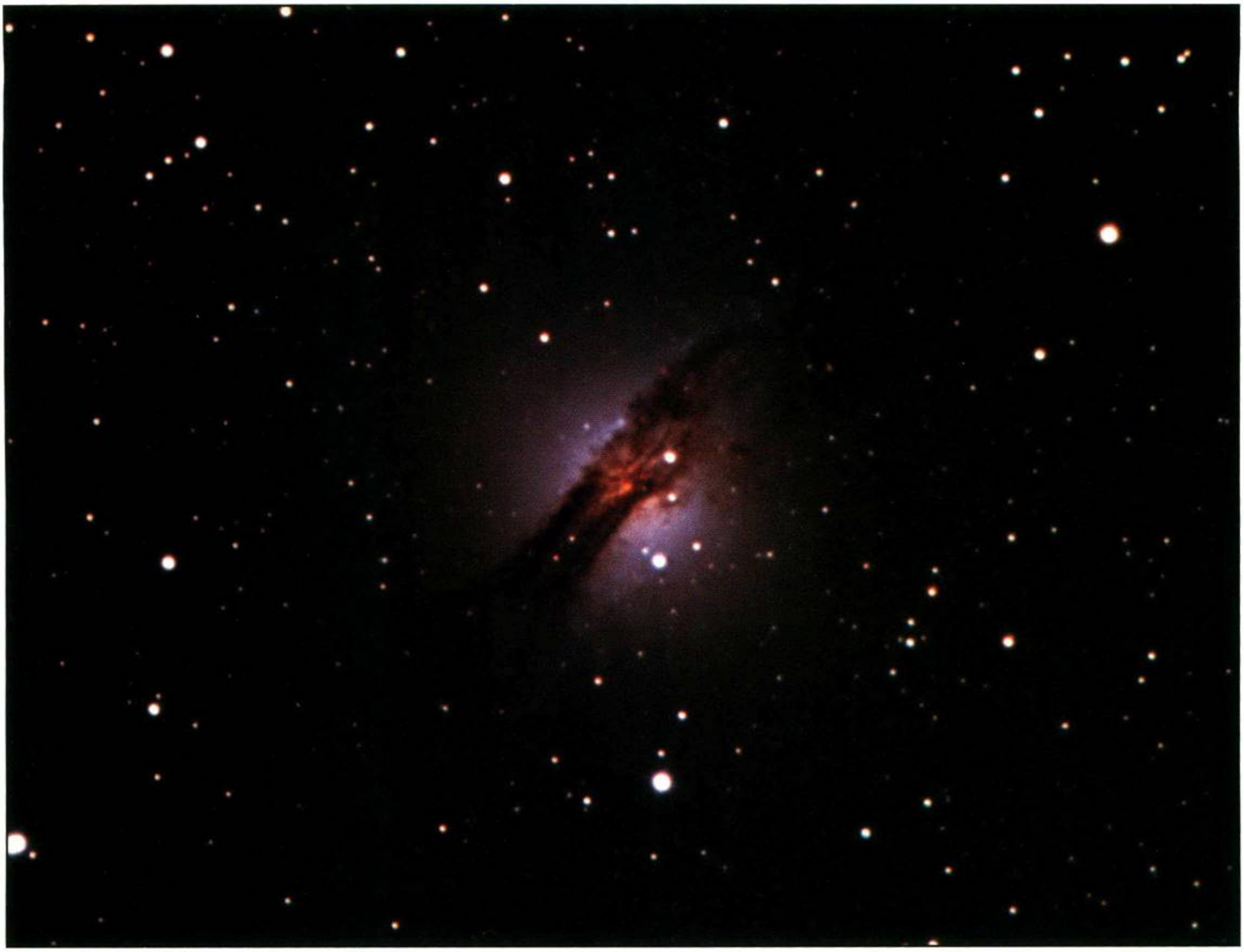
Continuing southward, the next galaxy to encounter is an inconspicuous object in Hydra, **NGC 3312**. This anemic galaxy, the first such identified, glows faintly at about 13th magnitude and spans a mere 3.6' by 1.5'. Nonetheless, the largest backyard telescopes or CCD imaging systems may resolve some of the complex structure of this galaxy's dust. NGC 3312 certainly presents itself as a challenge object for those who have already imaged the bright stuff.

Perhaps the strangest galaxy in the sky, **NGC 5128** in Centaurus, can be seen by observers in the Southern Hemisphere and those in the lowest latitudes of the United States. Called Centaurus A by radio astronomers, NGC 5128 is an enigmatic, explosive object. It resembles an elliptical galaxy bisected by a thick girdle of dark dust. At magnitude 7.0, NGC 5128 is an easy binocular target for low-latitude observers. For gazers at mid latitudes, it is diminished by atmospheric haze, but can still be an extremely rewarding object. The dark lane is

Dusty Galaxies for Backyard Scopes

Galaxy	R.A.(2000.0)Dec.		Mag.	Size	Type
M31 (NGC 224)	0h42.7m	41°16'	3.5	178' by 63'	Sb
NGC 253	0h47.6m	−25°17'	7.1	25.1' by 7.4'	Sc pec
NGC 681	1h49.2m	−10°26'	11.8	2.8' by 1.8'	Sb$^-$
NGC 891	2h22.6m	42°21'	10.0	13.5' by 2.8'	Sb
NGC 2146	6h18.7m	78°21'	10.5	6.0' by 3.8'	SBb$^-$ pec
NGC 2685	8h55.6m	58°44'	11.1	5.2' by 3.0'	Sb pec
M82 (NGC 3034)	9h55.8m	69°41'	8.4	11.2' by 4.6'	Pec
NGC 3077	10h03.3m	68°44'	9.9	4.6' by 3.6'	E2 pec
NGC 3312	10h37.0m	−27°34'	12.5_B	3.6' by 1.5'	Sb$^-$ pec
NGC 3628	11h20.3m	13°36'	9.5	14.8' by 3.6'	Sb
NGC 3718	11h32.6m	53°04'	10.5	8.7' by 4.5'	SBa pec
NGC 4438	12h27.8m	13°01'	10.1	9.3' by 3.9'	Sa pec
NGC 4565	12h36.3m	25°59'	9.6	16.2' by 2.8'	Sb
M104 (NGC 4594)	12h40.0m	−11°37'	8.3	8.9' by 4.1'	Sb$^-$
NGC 4753	12h52.4m	−1°12'	9.9	5.4' by 2.9'	Pec
M64 (NGC 4826)	12h56.7m	21°41'	8.5	9.3' by 5.4'	Sb$^-$
NGC 5128	13h25.5m	−43°01'	7.0	18.2' by 14.5'	S0 pec

This table provides **right ascension** and **declination** in epoch 2000.0 coordinates; V **magnitude** (except a subscript B, which denotes a B magnitude); **size** in arcminutes; and the revised **Hubble classification** of galaxy types.

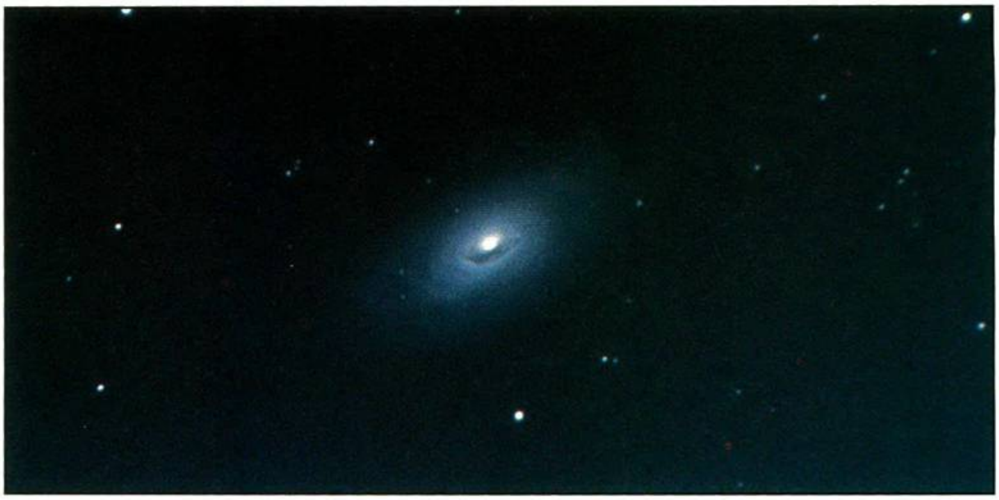


conspicuous in small telescopes. Larger apertures show the lane's ragged-edge.

Those objects discussed here are just a few of the dusty galaxies that can be seen in a single night in March. Consulting references like those mentioned in the Readings and Resources column in the back of this magazine will turn up many more examples of dusty galaxies. By observing them you'll discover an aspect of the power provided by your telescope. Not only can you see a galaxy, but you can pick out features in it. It's a significant step toward appreciating the true and partly hidden nature of the universe. □

Alan Goldstein is national coordinator of the National Deep-Sky Observers Society, an organization of fans of star clusters, nebulae, and galaxies. He has contributed to ASTRONOMY *frequently in the past.*

Centaurus A (NGC 5128)
by Andrew Peters
(20-inch f/5 reflector, hypersensitized Ektar 25 film, 150-minute exposure)

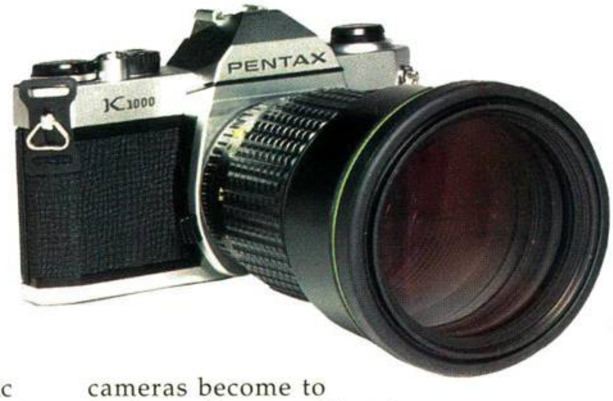


The Blackeye Galaxy (M64) in Coma Berenices
by Kim Zussman
(11-inch SCT at f/10, hypered Konica 1600 film, 80-minute exposure)

Choosing a Camera For Astrophotography

Photographing the night sky demands much from a camera. Here's what you should look for in a model that's up to the job.

By Michael Covington



So you've finally decided to shoot pictures of the sky. What kind of camera should you get? In a market brimming with all-electric, automatic cameras, it's important to look for certain features. Selecting the right new camera, even landing a bargain used one, is easy if you know what to look for.

First, the Basics

The best astrophotography camera is a 35mm SLR (single-lens reflex). An SLR camera accepts a variety of lenses, from wide angle right on up through telephoto. The camera attaches to a telescope, thanks to what's called a T-adapter.

The SLR lets you view and focus the image that falls on the film by means of a focusing mirror that directs light from the lens into the viewfinder. When the camera's shutter fires, the mirror flips up during an exposure while a shutter behind it opens to expose the film.

What you don't need in an astrocamera is an autofocus, auto exposure SLR. In fact, the automatic circuits in them only know how to take ordinary pictures, not astronomical ones. That's why new cameras suitable for astrophotography are harder to find than they used to be — manufacturers are automating most of their products. Astrophotography falls outside of what most automatic cameras can accommodate.

A GOOD ASTROCAMERA makes it easy to take fantistic pictures of many deep-sky objects, like this one of the Orion Nebula.

Dennis Staffne

For example, many automatic cameras have electric shutters. Lengthy time exposures during some forms of astrophotography might drain a camera's battery or trigger some fail-safe "power-saver feature" that ends the exposure. This factor alone rules out all but a few electronic-shutter SLRs.

Some cameras have electric shutters that offer a non-electric bulb setting specifically for time exposures. To see if a camera you are thinking about buying has this feature, fire its shutter on the "B" setting with no battery in the camera.

Look for still more "manual" characteristics in an astrocamera candidate.

An interchangeable focusing screen adds a measure of flexibility between regular daylight picture-taking and the stringent demands of celestial photography. The microprism or split-image screens in most cameras become to dark to focus with at f-ratios higher than f/4, which makes photography through most telescopes difficult. If the camera allows you to swap screens, install a fine matte screen that lets more light through the viewfinder.

Another good feature to look for is a mirror lock-up button. This lets you lock the viewfinder's mirror in a raised position before the shutter fires to reduce vibrations that can blur a picture.

Looking for a New Camera

Armed with this list of attributes, let's take a look at what the new camera market has to offer the burgeoning astrophotographer.

First some good news in this age of automatic cameras: If you have an ample budget, there are plenty of new cameras on the market with features well-suited for astrophotography. Three that stand out are the Nikon F3, Pentax LX, and Olympus OM-4T. It's no accident that all of these come from companies that also make microscopes and medical imaging instruments. Astrophotography may be the hobby of a select few, but medical photography goes on in every town every day, and its technical requirements are similar.

The Nikon F3 and Pentax LX are "do-everything" cameras; each is loaded with features and has an elaborate family of lenses and accessories. The Nikon, in particular, has a reputation for extraordinary ruggedness. It's the kind of camera that a busy newspaper photographer can rely on for years, and it accepts any Nikon lens made since the 1950s.

The Olympus OM-4 is optimized for pictorial and scientific photography, with a sophisticated multi-spot metering system and an unusually wide range of focusing screens. It lacks a mirror lockup button, but a system of shock absorbers built into the mirror's travel mechanism minimizes shutter vibration. Anyone buying an OM camera should be aware that Olympus is now realigning its product line. The Olympus selection of lenses, though ample, is not as large as it once was.

Companies that Deal in Used Cameras

KEH Camera Brokers
188 14th Street, Northwest
Atlanta, GA 30318
(404) 892-6905

Columbus Camera Group
55 E. Blake
Columbus, OH 43202
(614) 267-0686

Midwest Photo Exchange
3313 N. High Street
Columbus, OH 43202
(614) 261-1264

Brooklyn Camera Exchange
549 E. 26th Street
Brooklyn, NY 11210
(718) 462-2892

At the cheaper end of the price range is the Pentax K-1000, a 1960s-style camera that's affectionately been called the Volkswagen Beetle of SLRs. It lacks mirror lock and its focusing screen isn't interchangeable, but it takes the same fine lenses as Pentax's high-end LX and has a reputation for ruggedness. The Pentax K-1000 accepts K-mount lenses, probably the single most popular lens mount in the industry.

Another low-priced traditionalist is the Ricoh KR-5 Super II, which has a mirror lock button and takes Pentax lenses. It's harder to find than the K-1000, but well worth looking for.

Playing the Used Card

Save more money by looking for an astrocamera on the used market. Right now, the best buy is probably the Olympus OM-1. This venerable camera accepts the same lenses and focusing screens as the OM-4T, but has a fully mechanical shutter and a mechanical mirror lock. Budget $130 to $200 for an OM-1 (with a 50mm lens) and another $90 to have it cleaned, lubricated, and adjusted at a repair shop.

Other used SLRs in the marketplace are a little cheaper than the OM-1, but lack desirable features. The Pentax Spotmatic and Minolta SRT series are classic cameras similar to today's Pentax K-1000. Like the K-1000, they lack mirror lockup, but the Minoltas have an especially bright focusing screen. Used Nikon Fs, F2s, and F3s are also excellent buys, though they might run more money.

Avoid electronically controlled cameras such as the Olympus OM-10 and OM-G, which won't take time exposures without running down the battery. Also be wary of cameras for which few good lenses are now available, such as Miranda and Exakta.

If you plan to do terrestrial photography, find out whether the camera's light meter requires a 1.35-volt mercury battery. Many states have banned mercury batteries to prevent pollution of landfills, but the industry has not yet developed a satisfactory substitute. Such is the case with the OM-1. Never put a 1.5-volt alkaline or silver oxide battery in place of a mercury one without first consulting the manufacturer; in some cases the extra voltage can burn out the meter.

Unless you're positive there's nothing wrong with your used camera, plan on sending it to a repair shop to have it checked over. Repair shops are cropping up all over the country as photographers realize that their classic cameras need maintenance. These shops offer two kinds of repairs: a complete overhaul with a guarantee that the camera will continue to work perfectly for six months, and a simple repair of one problem with no guarantee of anything else. Most photographers want the first kind, which costs $80 or more; you may well make do with the second kind, which is cheaper.

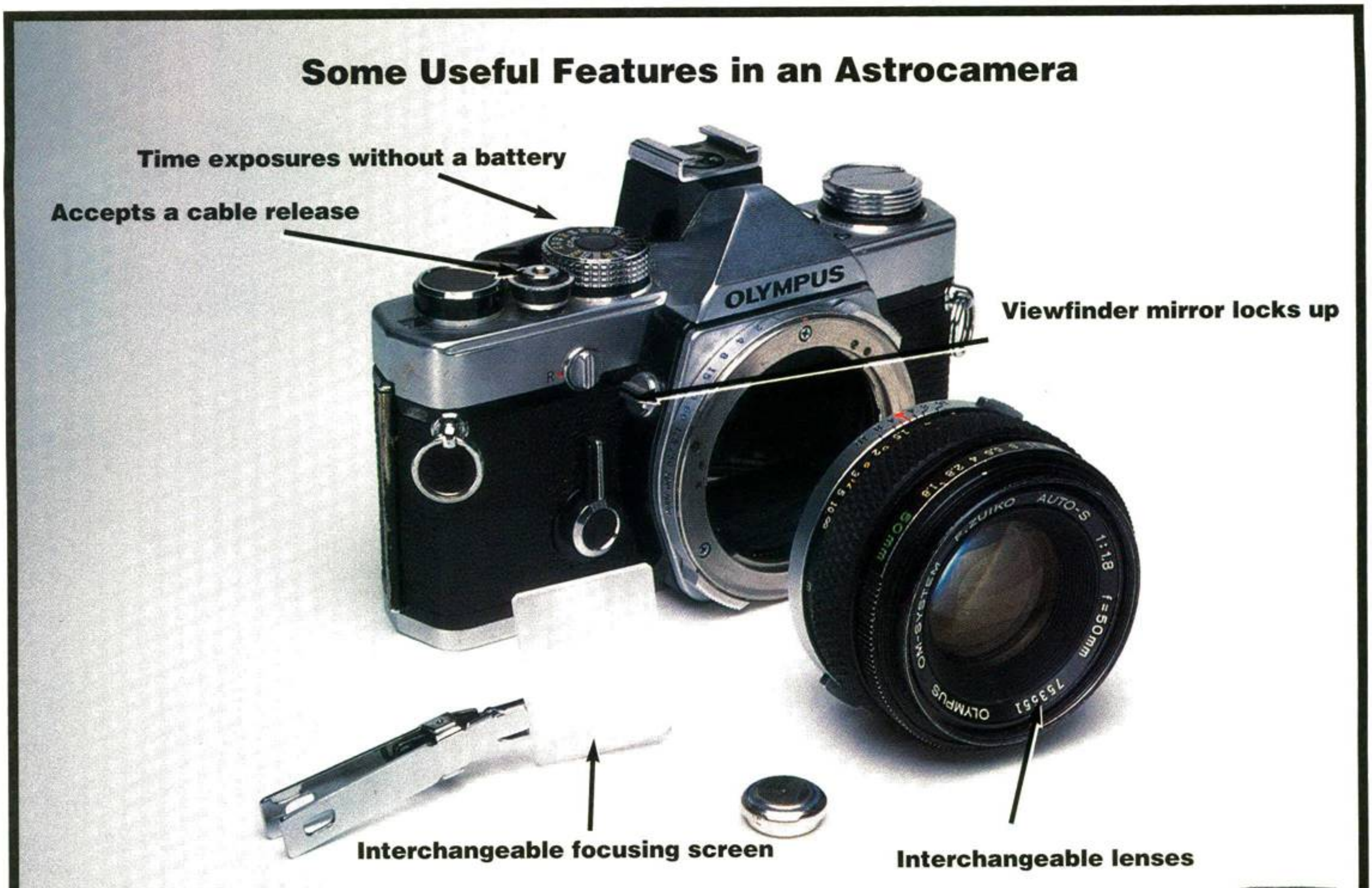
If the camera is more than 15 years old, its internal lubricants have probably dried out. Get it lubricated before any parts are damaged from seize ups. Also look for "foam rot" that makes foam mirror pads look crumbly or gooey. If the foam pads are sticky, the mirror may stick in its raised position after a long time exposure. Have the foam replaced by a repair shop before it causes problems.

How the Cameras Compare

Feature	Importance	Nikon F3	Pentax LX	Olympus OM-4T	Ricoh Pentax K-1000	KR-5 Super (not III)	Nikon IIF, F2	Olympus OM-1
Interchangeable lens	Essential	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Long exposures w/o batteries?	Essential	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interchangeable screens?	Desirable	Yes	Yes	Yes	No	No	Yes	Yes
Mirror locks up Usually	Desirable	Yes	Yes	No	No	Yes	Yes	Yes
Approximate selling price		$1500	$1200	$1100	$250	$250	$500	$200 (used)

Besides fixing cameras, repair shops can also tell you where to buy

Some Useful Features in an Astrocamera


Time exposures without a battery
Accepts a cable release
Viewfinder mirror locks up
Interchangeable focusing screen
Interchangeable lenses

All photos by ASTRONOMY: Darla Evans

used cameras in your area. Another source is *Shutterbug* magazine (P.O. Box F, Titusville, FL 32781; phone: 407-268-5010), which has ads for dozens of outlets as well as a calendar of camera swap meets nationwide. Every pawn shop has a few used cameras. Nowadays, used-camera dealers use standard price guides. As a result, prices will be about the same everywhere; it won't cost you much more to buy from an established dealer who offers a two-week return privilege.

For a real bargain, consider buying a camera that has defects you can live with, such as a dead light meter or some inaccurate shutter speeds. For example, I recently paid $20 for an old Mamiya/ Sekor that had a broken wire in the battery compartment, but was still perfectly usable for astrophotography. Many dealers unload defective cameras at the lowest possible price, since most photographers don't want them. Beware of shutters that jam; in the showroom, trip the shutter of the camera ten or twenty times to make sure it's going to work reliably, even if the speeds aren't accurate.

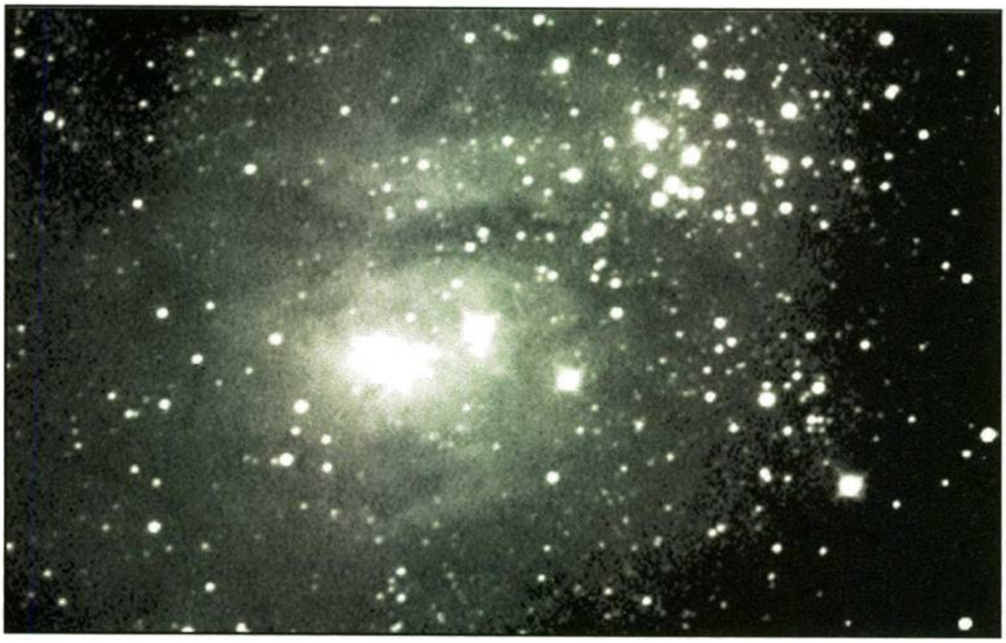
Regardless of whether you go used or new, astrophotography promises to become a lifelong passion. Take your time to find the right camera, be it new or used. Having the right tools, like a good camera, will make every moment in astrophotography both fun and exciting. ☐

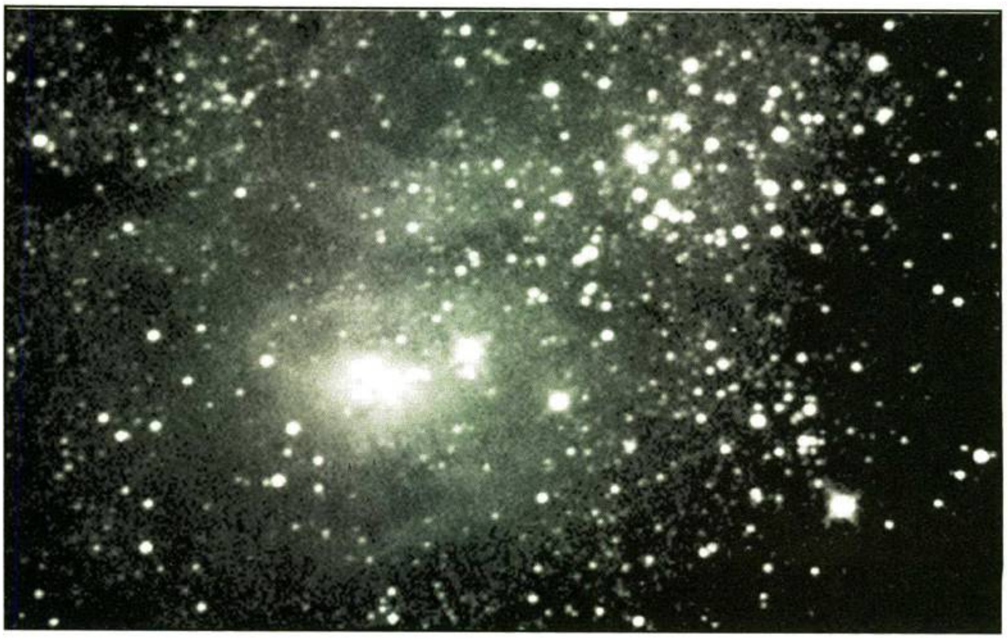
Michael Covington has been doing astrophotography for more than 20 years. During the day, he researches artificial intelligence at the University of Georgia in Athens. E-mail him at mcovingt@ai.uga.edu.

Beyond the Visible with CCDs

If you're imaging with a CCD camera, adding a near-infrared filter lets you see through nebulae and spot hidden details deep within galaxies.

Story and Images by Glenn Gombert, Paul Schrieber, and John Chumack





STAR FACTORIES such as the one buried in the Lagoon Nebula in Sagittarius become visible when imaged with near-infrared filters. The green image (top) shows what the eye might see in a scope, but the infrared image sees through the dust to clearly reveal the stars hidden *inside the* nebula.

Two of us (Glenn and John) had been trying our hand at making tricolor images of comets and deep-sky objects when we read "An Infrared View of Our Universe" by Ian Gatley in the April 1994 ASTRONOMY. That article showed that many deep-sky objects familiar to backyard astronomers look very different when viewed through "infrared eyes." It sparked our interest in imaging objects in the near-infrared, a part of the spectrum few amateur astronomers ever explore.

CCDs are ideal for this kind of project. Unlike film, which is largely insensitive to infrared light, CCDs retain about half of their peak sensitivity in the near-infrared region, around 800 to 900 nanometers. (Visible light ranges from the blue at 400 nm to the red at 700 nm.) In addition, lenses and the reflective coatings on mirrors for reflecting telescopes perform well through the near-infrared. This means your backyard telescope can do near-infrared CCD

imaging without any modification.

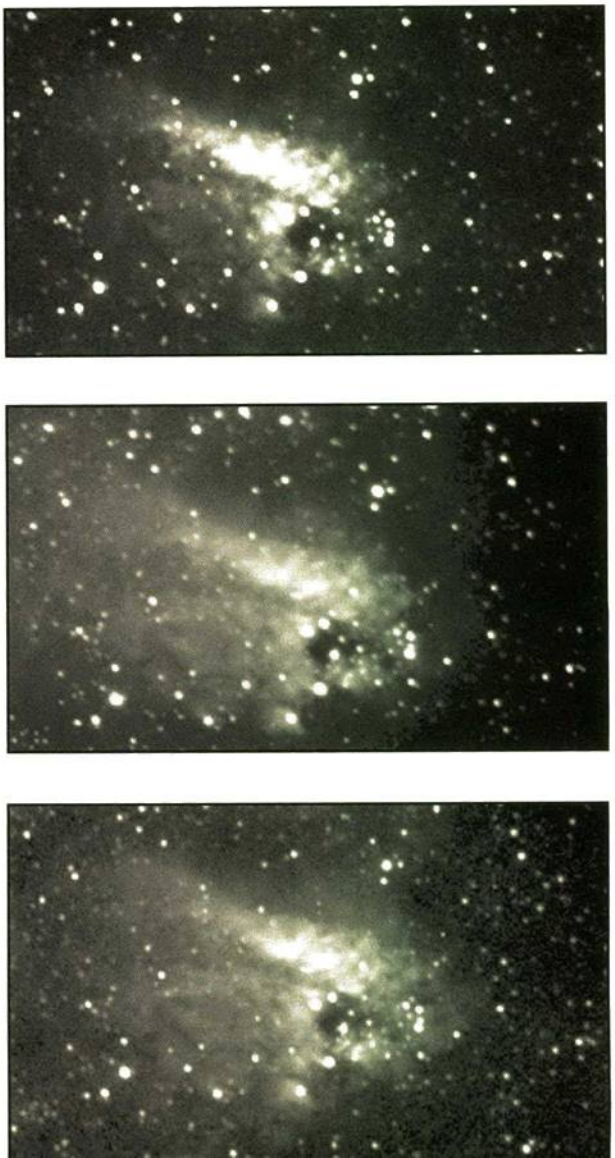
But to get near-infrared light by itself, we first had to prevent visible light from reaching the CCD chip. So we went to a camera store and bought the Kodak Wratten infrared filter. This stops all visible light while passing near-infrared radiation with wavelengths greater than 720 nm. This wavelength lies close to the longest wavelength visible to the human eye.

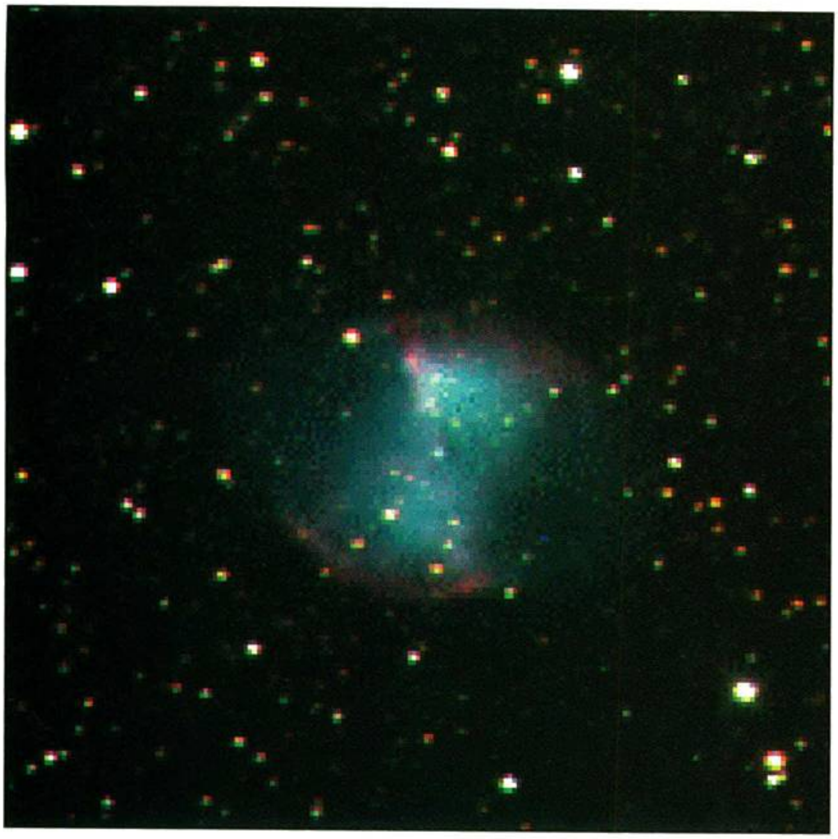
Richard Schwartz of Santa Barbara Instrument Group, makers of our ST-6 camera, suggested that we run the CCD camera as cold as possible for maximum sensitivity. He estimated that at 1100 nm the CCD would still keep approximately 5 percent of its best sensitivity. This means our rig would be about as sensitive as photographic film.

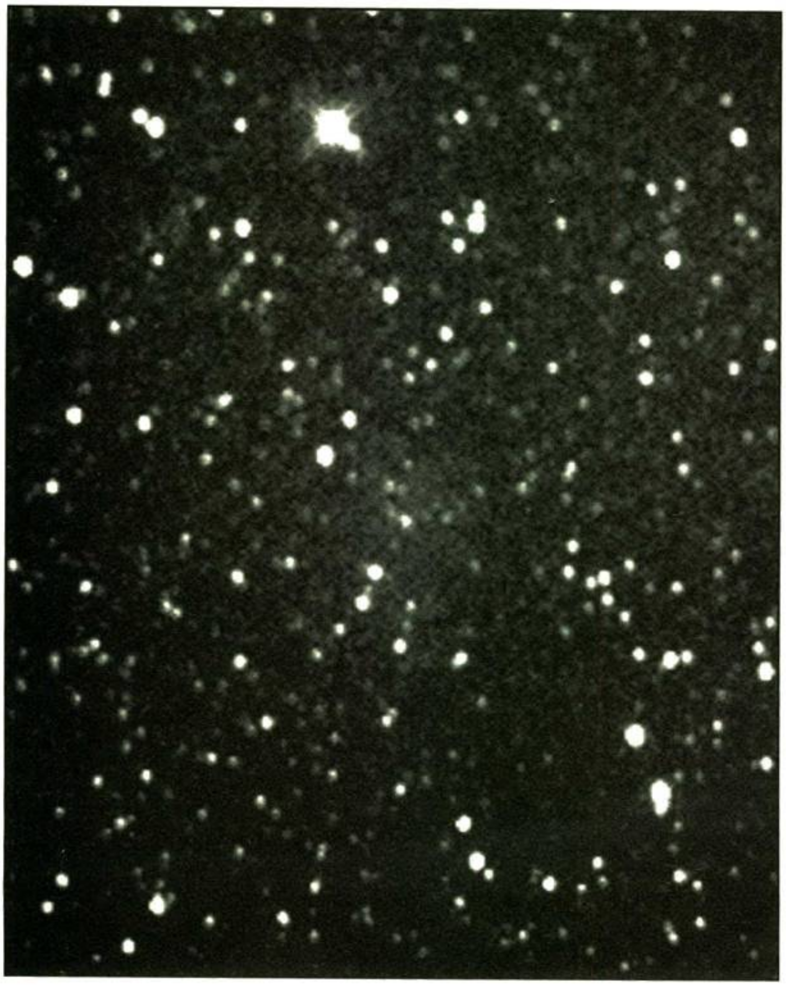
Some cold days in late fall 1994 let us to run the ST-6 camera at an internal temperature of –50° C. Using the Miami Valley Astronomical Society's observatory located at John Bryan State Park near Yellow Springs, Ohio, we took images of several deep-sky objects through the Wratten near-infrared filter. The frames included familiar nebulae and galaxies such as the Great Orion Nebula (M42) and the Whirlpool Galaxy (M51). The images revealed structural details strikingly similar in appearance to the images in Gatley's April 1994 article.

Excited by the results, we showed them to Paul Schreiber, another member of society. For many years

GOING DEEPER into the infrared cuts through dust and gas as seen in this sequence of green (right top), 700nm, and 900nm images of the Omega Nebula in Sagittarius.







NOW YOU SEE IT — and now you don't. The gas of the Dumbbell Nebula in Vulpecula disappears when imaged in the near infrared.

he has helped develop state-of-the-art technology in the Infrared Detector Laboratory at Wright-Patterson Air Force Base in Dayton, Ohio.

Paul pointed out that the quality of our filter might limit both the detail and the brightness measurements that we could potentially achieve using the ST-6 camera. Promoting our near-infrared imaging venture as a community-outreach project at Wright-Patterson, Paul got us some higher-quality filters. These included several Schott RG10 glass filters that pass light with wavelengths longer than 700 nm and a filter custom-made from a wafer of gallium arsenide that passes light with wavelengths longer than 900 nm. (Schott filters cost about $25 each and are available from many CCD companies. You can substitute the more commonly available RG9 filter for the RG10 we used. Instead of the gallium-arsenide filter, try the Schott RG850 filter for imaging at 900 nm.)

Now at this point, anyone familiar with infrared astronomy is probably wondering, "Why are these guys in Ohio and not on Mauna Kea? What about water vapor and atmospheric absorption and all those bad things that come with observing at low altitude?"

The answer is that these near-infrared filters take advantage of a clear window in the atmosphere's spectrum. Water vapor and carbon dioxide in Earth's atmosphere do indeed strongly absorb infrared light — except in certain wavelength bands, for example from 1300 to 1500 nm, from 1800 to 2000 nm, and from 2400 to 3500 nm. Professional astronomers wanting to observe objects in the infrared use wavelengths between these absorption bands — or they launch a satellite above the atmosphere.

In the near-infrared region we were trying to reach (from 700 to 1100 nm), the atmosphere transmits light fairly well. Not perfect, but it's okay. Moderately strong absorption occurs from 1100 to 1200 nm, but CCDs have little sensitivity at those wavelengths anyway. And when you go out past 1100 nm, you need specialized infrared detectors made from indium antimonide or mercury cadmium telluride. These detectors are expensive even for professional observatories and are presently well beyond the means of amateur CCD imagers.

One problem with our near-infrared window is the glow from the atmosphere that competes with radiation from deep-sky objects. Water molecules in the atmosphere emit radiation at 720, 815, and 935 nm and oxygen molecules radiate at 759 nm. In the future, we plan to see just how bad is the contamination of our near-infrared imagery by these molecular lines. We'll do this by comparing our wide-band, Wratten-filtered CCD images (which include these molecular emission lines) to narrowband-filtered CCD images, which don't.

Enough of theory — on to the observations. Our near-infrared gallery consists of images of several deep-sky objects. We took these using the ST-6 CCD camera with 6-inch, 8-inch, and 16-inch telescopes at the society's observatory. For most objects, we took one image using a green filter coupled with an infrared-blocking filter. This represents a visual view of the object. Then we made additional exposures using infrared filters at 700 nm and 900 nm. For several objects, we made tricolor images.

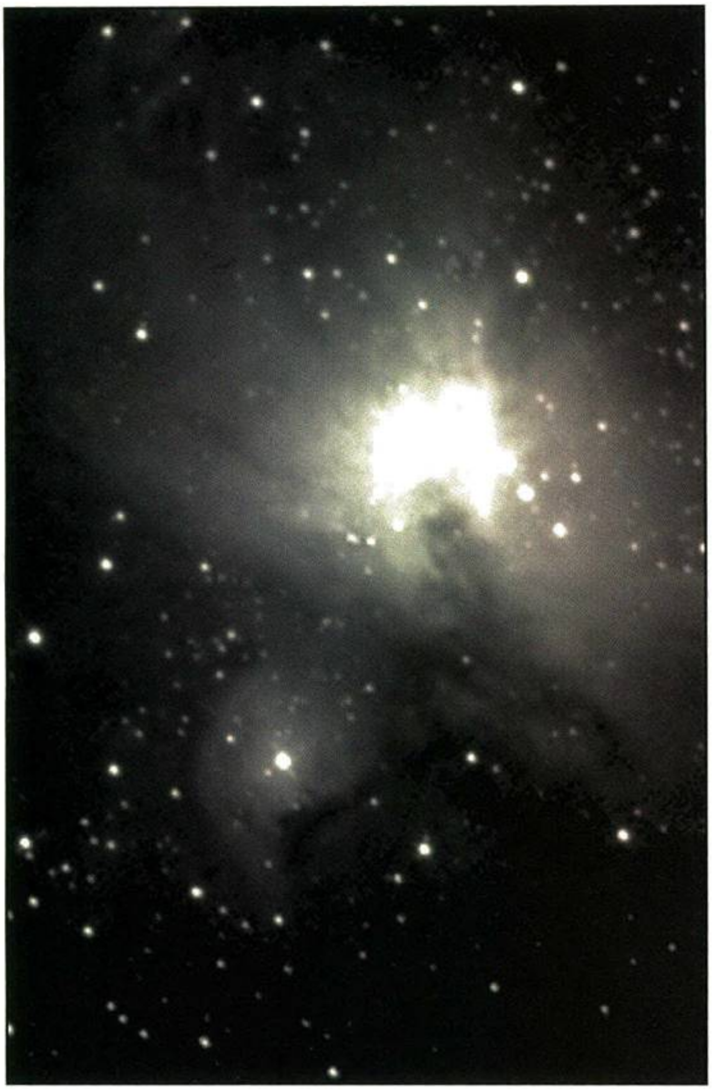
The most surprising results came from imaging nebulae. Bright emission nebulae are stellar factories. Only you can't see that directly because dust and gas obscure the stars that are forming inside. We imaged the Orion Nebula (M42), the Omega Nebula (M17) and Trifid Nebula (M20) in Sagittarius, and the Dumbbell Nebula (M27) in Vulpecula. What we found was that our CCD camera and near-infrared filter could peep into the obscuring dust and gas and reveal many of the underlying stars that are invisible in the green frames. That was a shock.

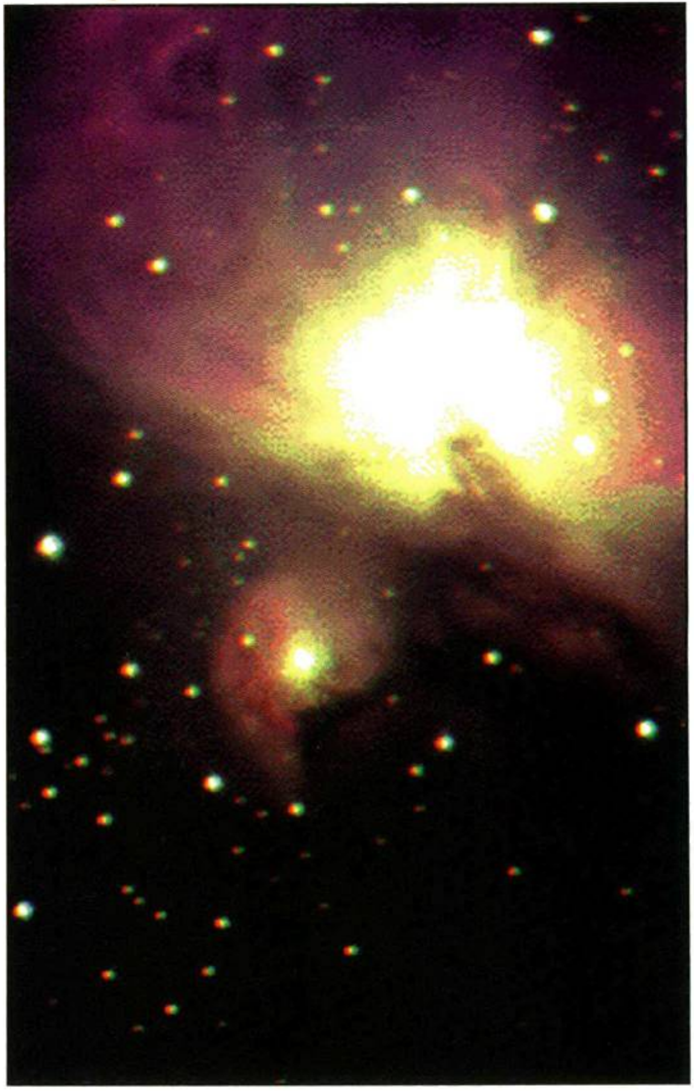
The image of the Orion Nebula demonstrates this dramatically. Taken through a 8-inch f/5 Newtonian telescope, the near-infrared image of M42 shows many more stars visible in the nebula than can be seen in the green ("visual") image. These stars are newly hatched in a cloud of molecular hydrogen gas located behind the Orion Nebula.

Another object that shows more detail in the near infrared is the Omega Nebula. The 900 nm image differs markedly from the 700 nm image of this star-forming cloud. The 900 nm filter penetrates deeper through the gas and dust of the nebula and reveals more hidden detail.

But the biggest surprise came when we imaged the Dumbbell Nebula. Taken through an 8-inch f/5 Newtonian, the green-light image looks pretty familiar, showing the view most backyard astronomers know and love. But at 900 nm, the Dumbbell disappears! The hydrogen, nitrogen, and oxygen emission that makes the nebula shine in the visible don't occur in the near infrared. Thus it's

NEW VIEWS of the Orion Nebula come to light by shooting in the near-infrared. A 900nm filter reveals structures in the dust cloud and stars being formed in this giant stellar nursery.





possible to look right *through* the nebula and inspect the region behind.

Nor is it nebulae alone that produce wonders. Some galaxies also give up secrets when imaged in the near infrared. For example, the companion to the Whirlpool Galaxy (M51) in Canes Venatici appears somewhat irregular in green-light visual images. But by penetrating the dust in the companion, our near-infrared frame (shot through a 16-inch f/4.5 Newtonian) uncovers a bar at its center.

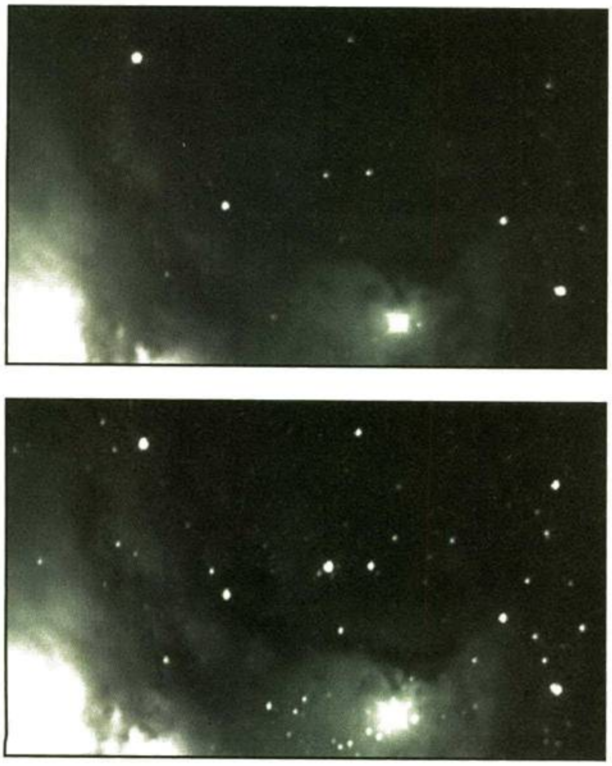
The unusual appearance of these objects in the near-infrared opens new horizons for backyard astronomers interested in CCD imaging. For decades we have been capturing familiar deep-sky objects using the visible portion of the spectrum. Now we can image these objects again in the near-infrared and for many, be rewarded with a completely fresh view.

Another possible area to explore is searching for astronomical objects using visible and near-infrared filters. Some objects that are inconspicuous on photographs such as the Palomar Observatory Sky Survey blue and red plates easily reveal themselves when imaged by CCD cameras fitted with near-infrared filters.

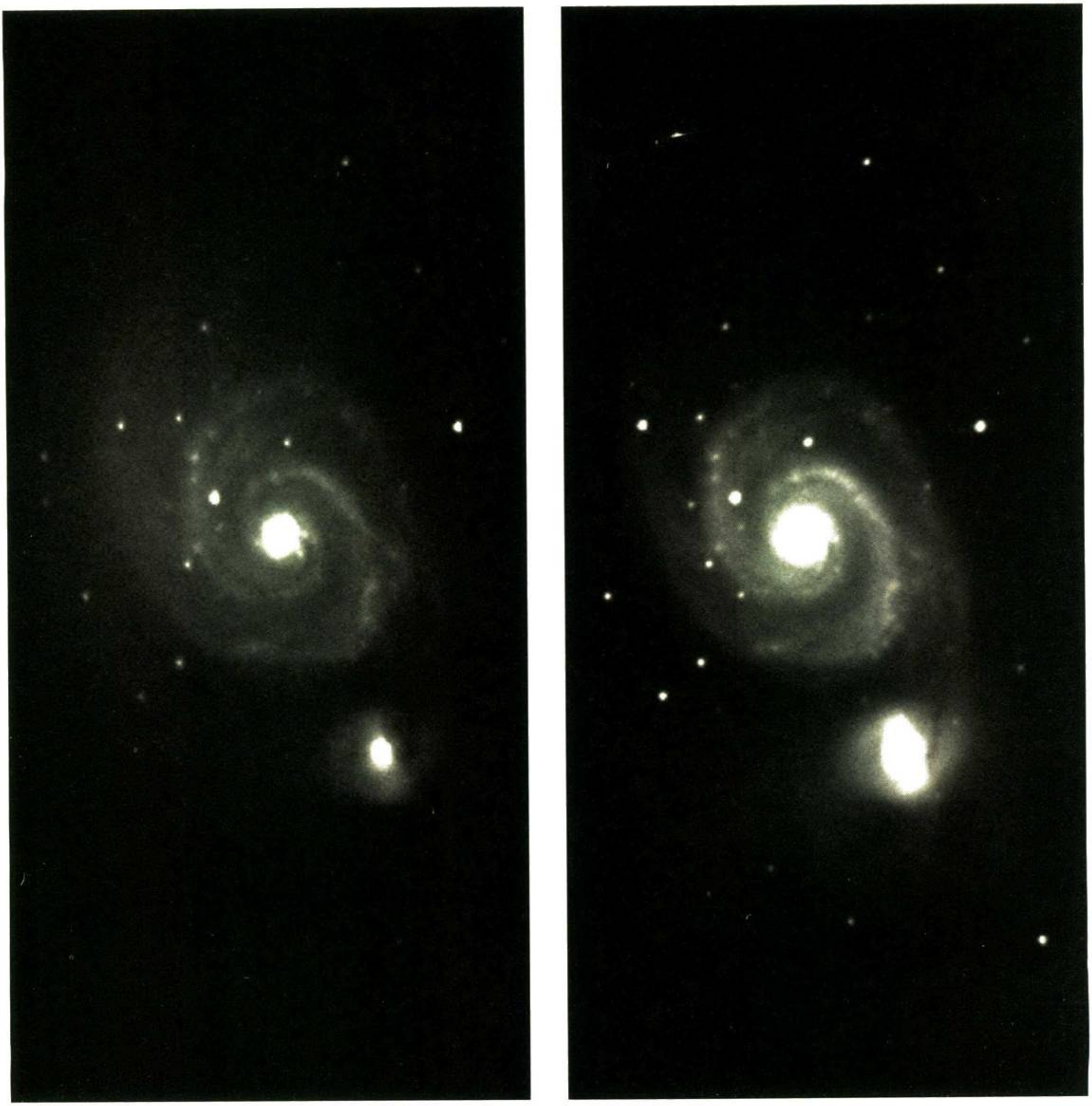
For example, Marshall McCall of York University in Toronto, Ontario, and Ronald Buta of the University of Alabama in Tuscaloosa recently found two new likely dwarf companion galaxies to Maffei 1, itself a companion to the Milky Way Galaxy. They imaged the region around Maffei 1 using the 36-inch Burrell-Schmidt telescope located on Kitt Peak in Arizona. A 10-minute exposure showed nothing in visible light, but two faint irregular galaxies stood out in a 10-minute exposure in the near-infrared. All right, those guys were using professional equipment. But how many similar discoveries await backyard astronomers equipped with a large scope, a CCD camera, and near-infrared filters? We'll never know until people give it a try.

A more advanced undertaking is near-infrared photometry. Some image-processing programs have brightness measurement routines that let you follow changes in variable stars and eclipsing binaries. Cool variables emit most of their light in the infrared and the near-infrared can penetrate dusty shells ejected by certain types of stars.

Another project is determining the positions of objects such as asteroids. Many of these are very red in color, and often brighter at infrared wavelengths than visual. Several CCD and image-processing pro-



UNSEEN STARS emerge in the infrared image of M43 (bottom) as compared to the green image (center), which is essentially what the eye sees in a telescope.



GLIMPSE THE BAR of the companion galaxy to M51 in Canes Venatici using a near-infrared filter.

grams have astrometry routines that enable you to align CCD images with stellar positions from the *Hubble Guide Star Catalog*.

Our pictures clearly demonstrate that the era of near-infrared imaging by amateurs is already here. All it takes is adding a simple filter to a CCD camera. For our next challenge, we plan to push our imaging out to longer wavelengths by building a new camera that's sensitive in the 1200 to 2200 nm region. Our goal is to match the images in Gatley's "An Infrared View of Our Universe," the article that started us near-infrared imaging in the first place.

Why should the professional astronomers have all the fun? ☐

Glenn Gombert (ggombert@erinet.com) and John Chumack are members of the Miami Valley Astronomical Society in Dayton, Ohio. Their previous article for Astronomy *was "Catching Comets with a CCD" in the February 1995 issue. Paul Schreiber works at the Infrared Detector Laboratory at Wright-Patterson Air Force Base in Dayton, Ohio.*

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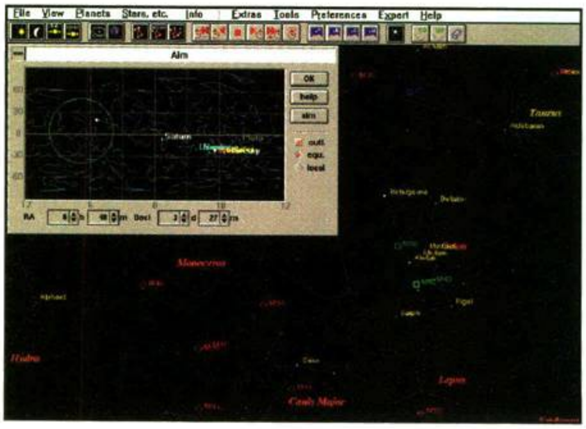

Distant Suns – First Light 1.0
Virtual Reality, 2341 Ganador Court, San Luis Obispo, CA 93401, (805) 545-8515, fax (805) 781-2259, or order at (800) 829-8754. Price: $99.95. Minimum requirements: 80386-based computer, PC with a 486SX microprocessor, 8 MB of memory, 5 MB of free space on a hard drive, CD-ROM drive, mouse, VGA display, DOS 5.0, and Windows 3.1. SoundBlaster-compatible audio is needed to view video clips. Virtual Reality recommends a math coprocessor for 80386-based computers or the use of an 80486-based computer.

Beginning astronomers will enjoy this multimedia planetarium program. *Distant Suns - First Light* replaces Virtual Reality's *Distant Suns* program on PCs. It displays 9,824 stars down to magnitude 6.7 using NASA's *SkyMap* and more than 1,500 deep-sky objects from the Messier catalog and the *New General Catalogue*. In fields less than 5° across, users can add stars down to 16th magnitude using the Hubble *Guide Star Catalog*.

As in most planetarium programs, users can turn stars, galaxies, and individual planets on and off as well as grid lines, constellation lines, star names, and other markers. Star label possibilities include common name, Henry Draper catalogue number, *Smithsonian Astrophysical Observatory Star Catalog* number, *SkyMap* number, or the Bayer designation (called the "Greek name" in *First Light*).

The viewpoint can be anywhere on Earth or any point in the solar system. Earthbound viewers can quickly navigate the sky using north, east, south, and west buttons. For space-minded viewers, a tool called Navigator makes changing viewpoints within the solar system as easy as clicking the mouse.

Users can choose between a horizon view or equatorial or star chart modes. With the landscape plotted in horizon mode, views are limited to 45° from the horizon (beware — the horizon line is now plotted 5° above the horizon). With the landscape turned off, the user can select a zenith view that provides an almost-all-sky map. The 180° map unfortunately overfills the rectangular window.

Stars plot as either white dots or in color. But that is the extent of customizing the plot. Label and line colors are constant as are type size and star size. In 800x600 mode, the star dots appeared tiny. Users can't switch the plot to red tones for viewing star maps at the telescope, but they can make printed copies for use at the eyepiece.

Moon observers will appreciate the celestial calendar (as will deep-sky observers wanting to find the dark of the New Moon) and the Moon map labeling lunar features. The moon phase or lunation plot is off though. The guide says the dates listed are for New Moon but in fact correspond to random phases in the lunar cycle.

Virtual Reality has forsaken a traditional printed manual for on-screen help, tutorials, and an on-line manual that uses Adobe Acrobat (supplied). It sometimes takes a while to find where your answer is located in these guides, but with the Windows environment, it's just a matter of clicking from one window to another.

The tutorials aim at beginners who want to learn the sky as much as how to use the program. They contain images, movies, and built-in animations using *First Light*. Another menu lets users browse images and movies when they no longer need the tutorials.

Distant Suns - First Light is a fine program for beginners with its tutorials and online help. Advanced amateurs may find the number of deep-sky objects and the lack of chart-customization controls limiting. — *Dave Bruning*

The Martian Chronicles

Brooklyn Multimedia, 1230 Avenue of the Americas, New York, NY 10020, direct order at (212) 698-7000. Price: $49.95. Minimum requirements: 25 MHz 80486DX-based computer, 8 MB of memory, double-speed CD-ROM drive, MPC-compatible sound board and speakers or headphones, mouse, SVGA display capable of 256 colors, and Windows 3.1. QuickTime is required but included on the CD-ROM.

Ray Bradbury's novel *The Martian Chronicles* has now become an interactive adventure game. The story of how two alien races affect each other's destinies comes to life with 3-D graphics, interviews with Bradbury, and special tools to explore the Red Planet. The game is not a linear adventure but has a rich set of puzzles to solve and clues to find, both of varying difficulty levels.

This isn't the typical program listed in AstroBytes. But if your interests also include science fiction and the weather is a bit cloudy some week preventing observing, this might be a pleasurable way to challenge your mind, or have a bit of fun.

Moontool correction

The January Astrobytes described a freeware program called *Moontool* that displays the Moon's phases. Laurence Marschall of Gettysburg College reports that this program provides the wrong Julian date because it registers a new day at 0h Universal Time. But if you want a display of the lunar phase, this program is more than sufficient. ☐

Software developers may send new programs and upgrades to AstroBytes, Astronomy Magazine, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out Astronomy's home page at http://www.kalmbach.com/astro/astronomy.html.

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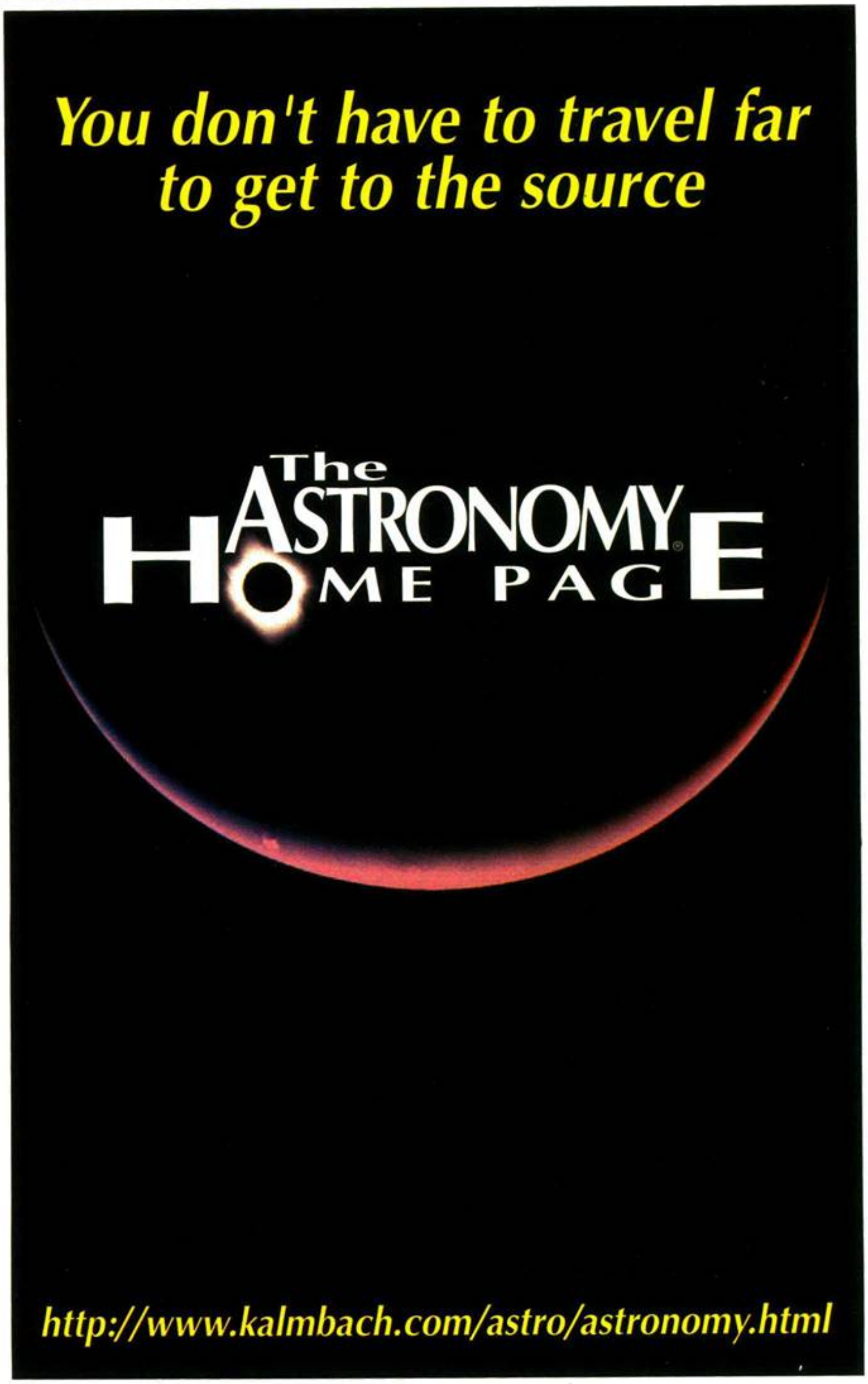
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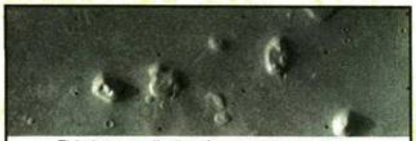

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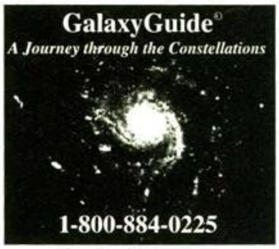

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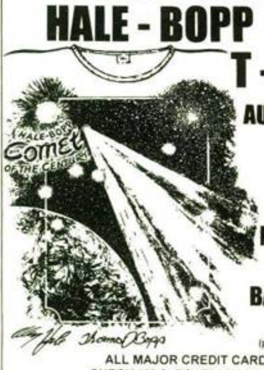
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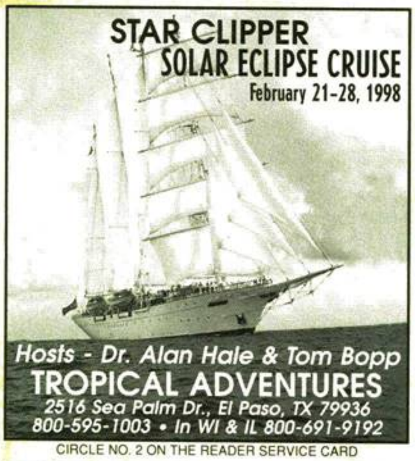

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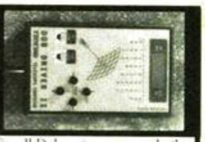

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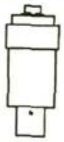

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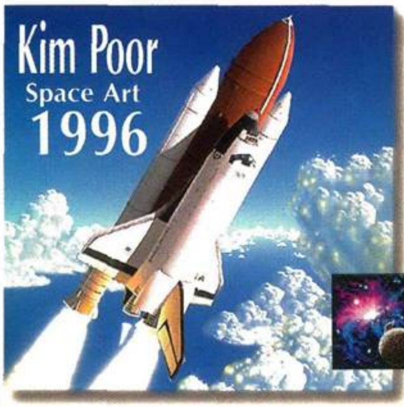

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Curved Earth and Space

by Larry O'Hanlon

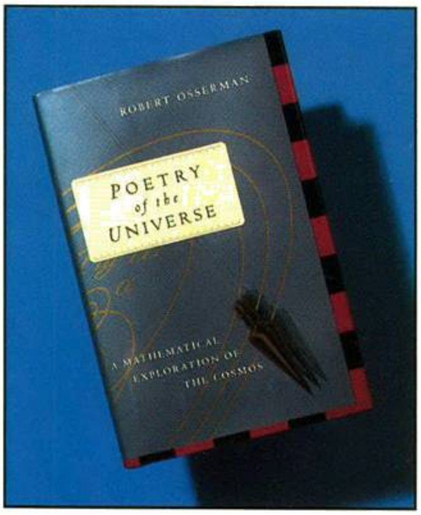
Poetry of the Universe: A Mathematical Exploration of the Cosmos

Robert Osserman, (Anchor Press, 1995), ISBN 0-385-47340-0, 210 pages, hardcover, $18.95.

Flat Earthers beware: This book by Stanford University mathematician Robert Osserman will disturb your peace of mind. In this compact volume, Osserman outlines the essential discoveries that led Columbus across the Atlantic and now challenge us to comprehend the shape of the universe (which many of us still incorrectly think of as spatially constant — cosmologically "flat"). There are no formulas to wade through and only the simplest figures adorn this almost pocket-sized book.

Osserman discusses the historical context of Gauss, Eratosthenes, Peano, von Koch, Hubble, Maxwell, and many others who have brought us to our current understanding of the universe. If you are not sure how these names relate to the ways we perceive our universe today, this book can be a real eye-opener and a handy reference. Both experts and novices of physics, mathematics, and astronomy can benefit from reading it.

Among the most interesting aspects of this book is how deftly historical myths are dispelled and explained. For instance, most people have heard that Columbus did not actually "discover" the Earth was round. But less renown is the story of those who did figure it out. By the 4th century B.C., people had determined our world's spherical shape by simply looking at the stars. Seeing how Polaris changes elevation above the northern horizon as one travels north or south was compelling evidence of a curved Earth. Knowing this, it was a just a geometrical (a word that literally means "Earth-measuring") hop, skip, and a jump to calculating Earth's circumference. Eratosthenes did that some 2,200 years ago, using gnomon to measure the angle of the Sun on the summer solstice, along the Nile River. His value was about 25,000 miles — remarkably close to the modern measurements of 24,902 (equatorially) and 24,860 (over the poles).



Columbus' 1492 achievement was to put that geometrical determination to the test. But Columbus favored Ptolemy's smaller and less accurate value of about 20,000 miles. Columbus and his men were lucky that the Americas got in the way and saved them from certain dehydration and starvation. Royal mathematicians in Portugal suspected that Columbus was a bit optimistic. They were also concerned that any ship venturing too far south might not be able to return "up hill" to the Northern Hemisphere. These doubts are among the reasons Columbus had to turn from his own king and appeal to Spain for financial backing.

Osserman builds from these rather ancient, but often misunderstood incidents, to discuss the modern-day significance of Möbius strips, the discovery of "buckyballs," and how satellite images of the cosmic background radiation may be as conceptually revolutionary as Eratosthenes' work. Yet Osserman retains a sense of wonder. Just in case readers begin to think scientists actually understand the universe, Osserman cites a famed Einsteinism, "The most incomprehensible thing about the universe is that it's comprehensible." In other words: Yes, we can describe the way things work mathematically, but just why math works is a mystery. The universe is inexplicably explicable.

These stories exemplify how scientific and mathematical concepts have had profound impacts on history and the very way we think about and interpret our surroundings. We believe in molecules, the roundness of Earth, and that we live in a suburb of the Milky Way. Our ancestors thought differently. The influences of mathematical science are so great, in fact, that after reading *Poetry of the Universe* it seems almost unbelievable that modern history books are written without special attention to the place of math and science in past societies. Television and historical novels have a tendency to revise the supposed thinking of our ancestors so that they seem to be twentieth century people who said "thee" and "thou," and who had just a few holes in their understanding of things. It's simply not so. This book reminds us that it was once just as hard to comprehend our spherical planet as it is today to think beyond a "flat" universe. It also makes you wonder what folks in the year 2400 will think of our quaint view of the universe.

Larry O'Hanlon is a contributing editor to EARTH magazine.

Other Books

Astronomy

Simon and Jacqueline Mitton, (Oxford University Press, 1996), ISBN 019-521169-3, 186 pages, hardcover, $25.

This volume, part of the Young Oxford Books series, is an encyclopedia for preteens and up. The first quarter of the book comprises a section called "The Challenge of Astronomy," which describes how astronomers learn about celestial objects and measure their distances. It also discusses our place in the universe and the motions of planets in the solar system. The remainder of the book characterizes in appropriate detail the planets, the Sun and stars, the Milky Way Galaxy, other galaxies, quasars, and the universe.

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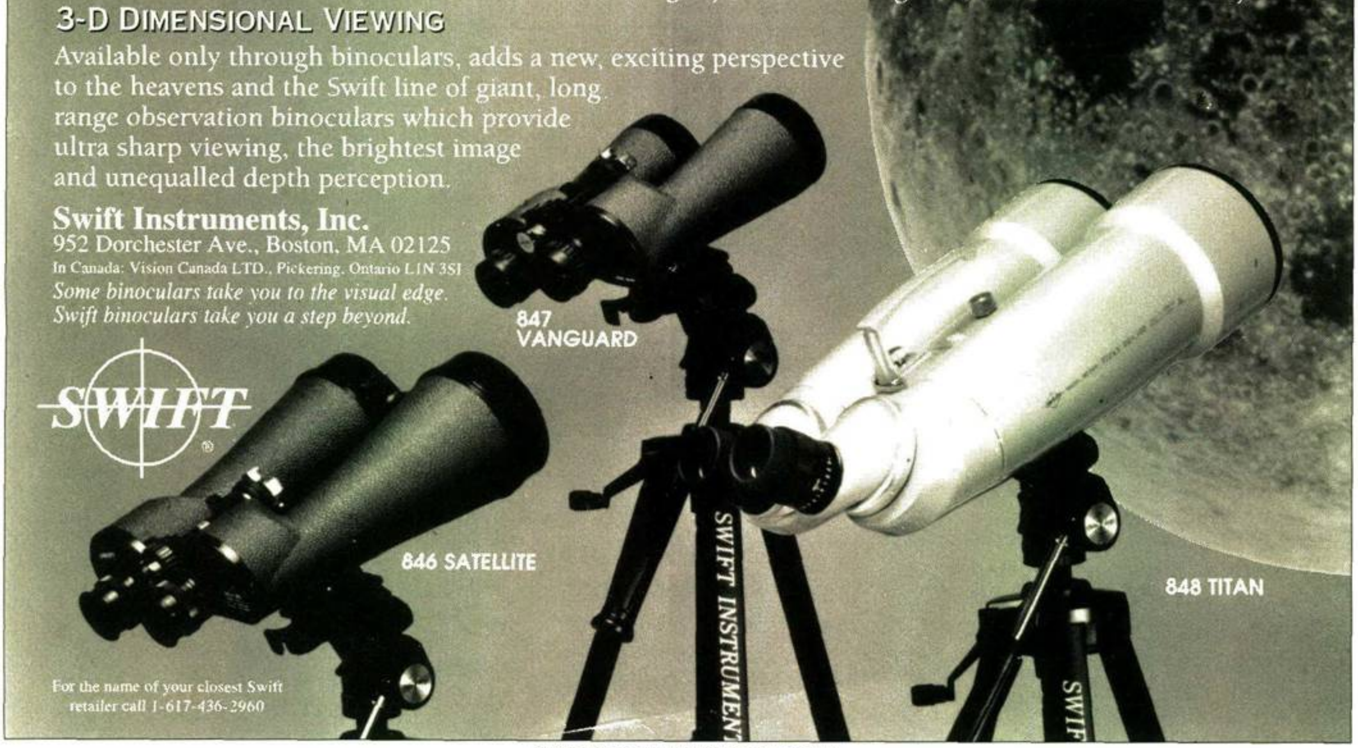

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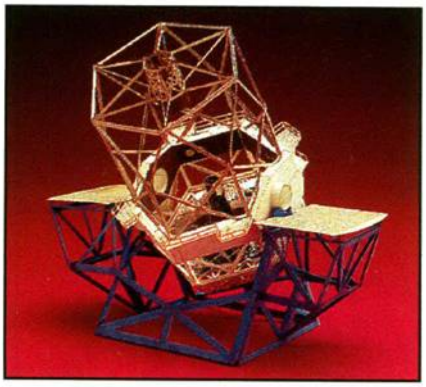

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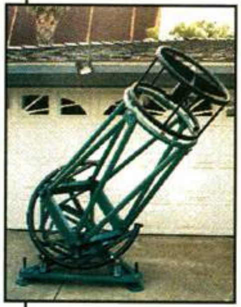
Build your own 1:170 scale model of one of the twin 10-meter Keck telescopes with this new kit from Space Craft International. The model has 44 parts laser-cut from 100 percent recycled heavy card stock, with Keck's optics represented by parts laminated in metal foil. Other components lithographed in color realistically portray the telescope. Keck's unique system of computer-controlled actuators that support a segmented main mirror are accurately shown. The model also tilts in altitude. Each kit comes with an 11" by 17" illustrated fact sheet that has suggestions on how to display the finished model, which stands 5 ¾" tall. The model assembles with white glue you provide.

Space Craft International, P. O. Box 61027 Catalina Station, Pasadena, CA 91116-7027. Phone: (818) 793-4300; fax, (818) 793-4233; e-mail, SCIkits@aol.com. Keck Telescope Science Kit: $14, post paid within North America; other countries add $5 for shipping and handling; California residents add 8% sales tax.

Split-ring Equatorial Telescope

L-5 Systems plans to make available through dealers its version of the popular split-ring equatorial telescope. The L-5 24D's frame is made of cast steel bolted and welded together for stability. It comes with built-in heavy duty, adjustable base pads for easy leveling. The frame is supported on a 48-inch-diameter, horseshoe-shaped ring that forms the bearing surface for the telescope's right ascension axis. Both the RA and declination axes are driven by DC motors controlled with a dual-axis drive corrector. The scope's 24-inch f/3.8 thin-thickness primary mirror sits in a removable mirror cell. A 360° rotating cage holds the secondary mirror, which obstructs 18.9 percent of the primary mirror's diameter. Eyepiece height is 92 inches when viewing at the zenith. The entire scope weighs 375 pounds and breaks into three parts for transport.

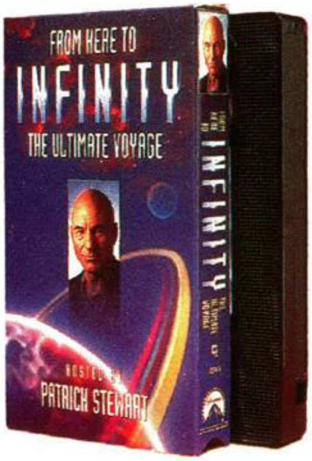


L-5 Systems, 3709 Orion Drive, La Mesa, CA 91941. Phone: (619) 469-5175. The L5- 24D Split-ring Equatorial Telescope: $13,900, plus shipping.

Patrick Stewart's Universe

English actor Patrick Stewart, who plays Star Trek's Captain Jean-Luc Picard, takes you on a personalized tour of the cosmos in an educational videotape released by Paramount Home Video. *From Here to Infinity: The Ultimate Voyage* uses lively computer animation and the latest in space photography to fully explore the solar system, our Milky Way Galaxy, and the universe beyond. Along the way, viewers learn about black holes and stop to probe a supercluster of galaxies. The 43-minute program has Dolby stereo sound and comes in Beta or VHS formats. Mail-order customers receive a free space poster.

Paramount Home Video, 5555 Melrose Avenue, Hollywood, CA 90038-3197. Phone: (213) 956-5000. From Here to Infinity videocassette: $14, plus $3.50 shipping.



Telescope Dust Cover

Rhondele's Excess Baggage makes telescope dust covers to cap any sized telescope on the market. Each "night-sky" blue cover is made of water-resistant Cordura and lined with black, scuff-proof vinyl. The cover fits snugly over the open end of a telescope's tube (shown here on a 13.1-inch Dobsonian).

Rhondele's Excess Baggage, 955 N. Main, Buffalo, WY 82834. Phone: (307) 684-5152. The Star Gazing Dust Cover: $10.95, plus $3.50 shipping. Visa, Master Card, Discover, and Cashier's Check accepted.

Streetlight Shield

Outdoor Lighting Associates offers the backyard astronomer a solution to unshielded streetlights. Their Hubbell Skycap slips over an existing streetlight's fixture to direct light down where it belongs rather than up into the sky. The Skycap replaces most of the transparent shields found on NEMA-head type streetlights. Just unclip the existing shade (top) and replace it with the aluminum Skycap (bottom). Installation takes only a few minutes and normally does not require tools.

Outdoor Lighting Associates, 1208 Wilson Ave., Ames, IA 50010-5426. Voice/fax, (515) 233-0117, e-mail, OutdoorLtg@aol.com. The Hubbell Skycap Streetlight Shield: $35, plus $10 shipping and handling. Quantity discounts for orders of ten or more.

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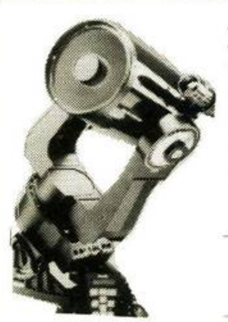

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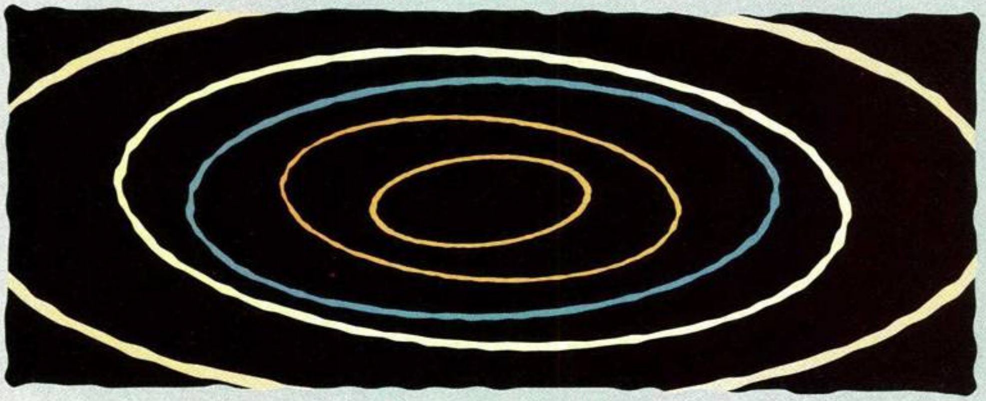

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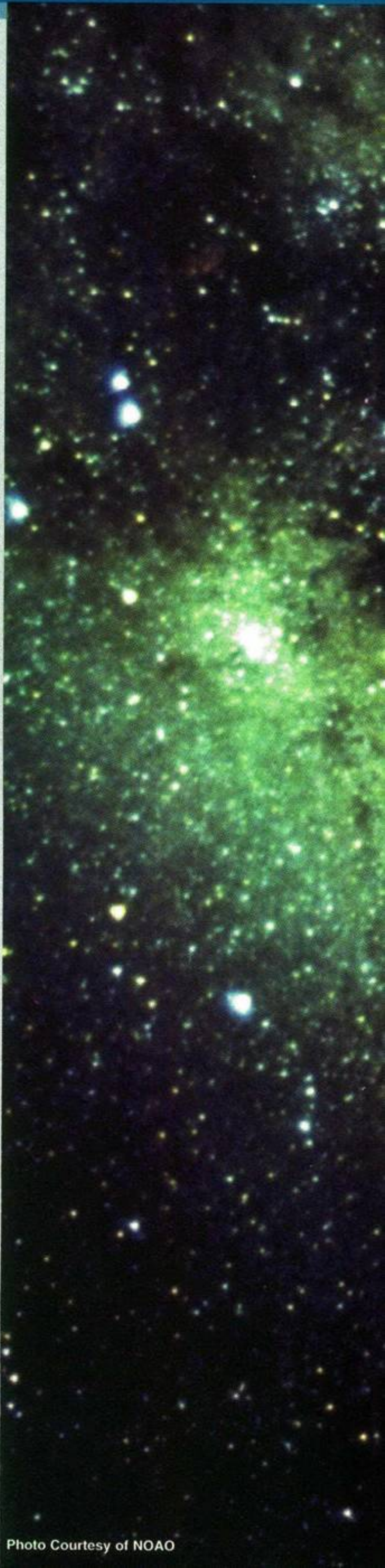

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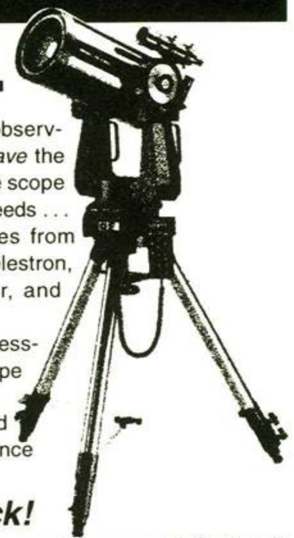

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READINGS & PHOTOFACTS

Planet for Real? (page 34)

Web site: http://zebu.oregon.edu/51peg.html

"A Jupiter-Mass Companion to a Solar-Type Star," by Michel Mayor and Didier Queloz, *Nature*, November 23, 1995, pp. 355-359.

NEAR Asteroid (page 42)

"Galileo Views Gaspra" by Rich Talcott, ASTRONOMY, February 1992. First results from Galileo's flyby of Gaspra.

"Interplanetary Fugitives" by Lucy-Ann McFadden and Clark R. Chapman, ASTRONOMY, August 1992. Profiles near-Earth asteroids, such as Eros.

"All in the Family" by Dan Durda, ASTRONOMY, February 1993. Astronomers study fragments of asteroid to learn how the asteroid belt evolved.

Johns Hopkins University/Applied Physics Laboratory's NEAR home page: http://hurlbut.jhuapl.edu:80/NEAR/

NASA headquarters Discovery program home page: http://mercury.hq.nasa.gov/office/discovery/

Tilt-a-Whirl Astronomy (page 50)

The Astronomical Companion, by Guy Ottewell (1979, Astronomical Workshop, Furman University, Greenville, SC 29613). Explains motions of Earth, the Moon, and the planets in space.

Choosing a Camera (page 77)

"Seeking the Best 35mm Camera" by Alan Dyer, ASTRONOMY, September 1993. Evaluates manual cameras and star tests commonly used lenses. ☐

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p. 61: Pedro Ré; **p. 63:** Mace Hooley, Fuji 100, 20-min. exposure; **p. 64:** Jean Dragesco, 14-inch SCT, Ektachrome 200, March 16, 1981; **p. 65:** L. H. Price, 260mm lens at f/5.6, Fuji 400, 1-sec. exposure on April 6, 1989; **pp. 66-67:** Luke Dodd, 105mm lens at f/4, hypersensitized Fuji 400, 20-min. exposure; **p. 68, top left:** Lee C. Coombs, 10-inch f/5 reflector, 3M 1000, 15-min. exposure; **top right:** Preston S. Justis, 10-inch f/6 reflector, hypersensitized Tech Pan, 60-min. exposure; **middle left:** Bernard Abrams, 10-inch f/5 reflector; **middle center:** Lee C. Coombs, 10-inch f/5 reflector, 103a-O, 10-min. exposure; **middle right:** Martin C. Germano, 8-inch f/6 reflector, hypersensitized Tech Pan, 90-min. exposure; **bottom right:** Bruce Balick, Kitt Peak 2.1-meter reflector, NOAO; **p. 69, left:** Bruce Balick, Kitt Peak 2.1-meter reflector, NOAO; **right:** Martin C. Germano, 8-inch f/10 SCT, 103a-F, 30-min. exposure; **bottom:** Martin C. Germano, 8-inch f/5 reflector, hypersensitized Tech Pan, 45-min. exposure; **p. 70:** Jason Ware, 16-inch f/10 SCT, hypersensitized Fuji G800, composite of two 30-min. exposures; **p. 71, top:** Rudolph Schild, Smithsonian Astrophysical Observatory; **bottom:** Palomar Mountain Observatory; **p. 72, top:** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan, 250-min. exposure; **bottom:** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan, 151-min. exposure; **p. 73, top:** Chuck Vaughn, 12.5-inch f/9 Ritchey-Chretien, hypersensitized Tech Pan, 90-min. exposure; **p. 74:** David Healy, 14-inch SCT at f/5.5, hypersensitized Fuji, 30-min. exposure; **p. 75, top:** Andrew Peters, 20-inch f/5 reflector, hypersensitized Ektar 25, 150-min. exposure; **bottom:** Kim Zussman, 11-inch SCT at f/10, hypersensitized Konica 1600, 80-min. exposure; **p. 105, top:** Huguette Guertin, 700mm Maksutov-Cassegrain at f/8, ISO 25, 1-sec. exposure on October 24, 1995, taken from India; **bottom left:** Jay Pasachoff and Rana Nichols-Kiley, taken October 24, 1995, from Rajasthan, India; **bottom right:** Yves Delaye, 4-inch apochromatic refractor at f/10, Ektachrome 100, 1/500-sec. exposure taken on October 24, 1995, from Pehersar, India; **p. 106, top left:** Bob and Janice Fera, 11-inch SCT at f/10, hypersensitized Fuji Super G 800, composite of two 120-min. exposures; **top right:** Thomas A. Dobbins, 36-inch Crossley refractor at Lick Observatory operating at 588x and 1186x on Aughust 11, 1995; **middle:** Gerald Rhemann, 7.5-inch Schmidt camera at f/1.7, hypersensitized Tech Pan, 4-min. exposure on October 5, 1995; **bottom:** H. J. P. Arnold, hydrogen-alpha composite image taken August 10, 1995; **p. 107:** Michael Stecker, 5-inch f/6 refractor, hypersensitized Fujicolor 800, composite of two 50-min. exposures; **p. 108, top:** Tim Puckett, 12-inch f/7 SCT, ST-6 CCD camera, 300-sec. exposure taken October 17, 1995; **middle:** Al Kelly, 32-inch f/4 reflector, Cookbook 245 CCD camera, composite of three 15-sec. exposures; **bottom:** Keith Snyder, Steve Messner, Bob Elliott, and Paul Nelson, 12-inch reflector, STAR I CCD camera, 160-sec. exposure; **p. 109, top:** Giovanni dal Lago, 11-inch SCT at f/30, Starlight Xpress CCD camera, Daystar 0.6Å hydrogen-alpha filter, taken April 17, 1995; **bottom:** Gérard Therin, 10-inch SCT at f/38, Hi-Sis22 CCD camera, 0.2-sec. exposure; **p. 110:** Vince and Maggie Farnsworth, 4-inch f/5 refractor, Fuji SG 800, composite of two 35-min. exposures.

MEETINGS & EVENTS

March 17-20

Visual Communications and Image Processing, Twin Towers Hotel, Orlando, Florida. Sponsored by the International Society for Optical Engineering. Contact SPIE, P.O. Box 10, Bellingham, WA 98227-0010, (360) 676-3290, spie@spie.org.

March 18-22

Lunar and Planetary Science Conference, NASA Johnson Space Center, Houston, Texas. Co-sponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. Contact LeBecca Simons, LPI Publications and Programs Department, 3600 Bay Area Boulevard, Houston, TX 77058-1113, (713) 486-2158.

April 11

Astronomy Day, Dreyfuss Planetarium, Newark, New Jersey. Sponsored by The Newark Museum. Contact Kevin Conod, Dreyfuss Planetarium, Newark Museum, University Heights, P.O. Box 540, Newark, NJ 07101-0540.

April 13

Virginia Association of Astronomical Societies Convention, Chesapeake Planetarium, Chesapeake, Virginia. Hosted by the Back Bay Amateur Astronomers. Contact Robert J. Hitt, Chesapeake Planetarium, 300 Cedar Road, Chesapeake, VA 23320, (804) 547-0153.

April 14

Northeast Astronomy Forum and Telescope Show, Holiday Inn, Suffern, New York. Sponsored by the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street, Closter, NJ 07624-1709, (201) 768-6575.

April 18-21

Peach State Star Gaze, Jackson, Georgia. Sponsored by the Atlanta Astronomy Club, Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278-4463, (770) 979-9842, 102745.313@compuserve.com.

April 19-21

Astronomy Workshop, near Topeka, Kansas. Contact B. Culbertson, P.O. Box 149, Harveyville, KS 66431. ☐

Please send notices at least four months in advance to Meetings and Events, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612, tstaedter@astronomy.com.

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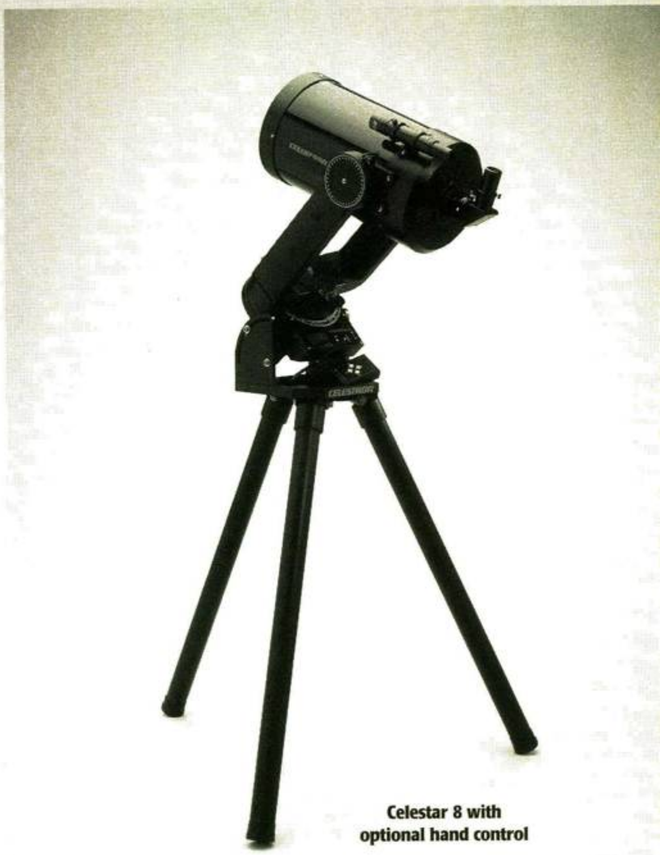

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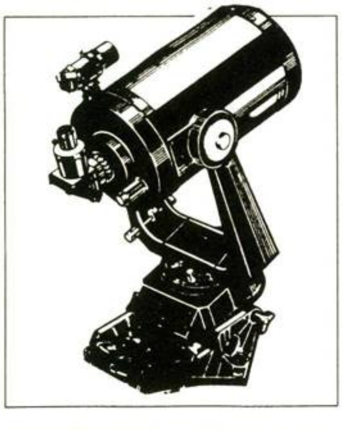

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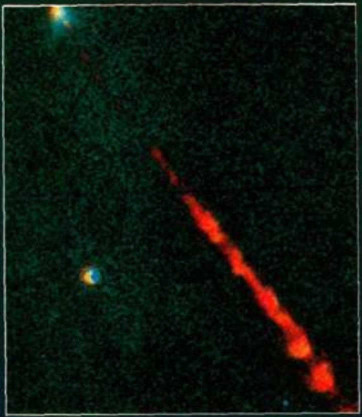

Jeff Hester, Arizona State University

FROM ASHES TO STARS

Astronomers have changed their ideas about stars gently forming in collapsing gas clouds. The real story is a violent one of vast outflows, whirling disks, and hypersonic jets.

THE DAY THE DINOSAURS DIED

An unprecedented number of species perished after a huge asteroid smashed into Earth 65 million years ago. Here's what really happened that fateful day.

SOLAR ECLIPSE OVER ASIA

Most of the shadow chasers who trekked to southern Asia last October enjoyed clear skies and brought home some remarkable photos.

AN APRIL SHOWER

The Lyrid meteor shower won't bring May flowers, but with the Moon out of the way, observers can expect the night sky to bloom with incinerated bits of comet debris.

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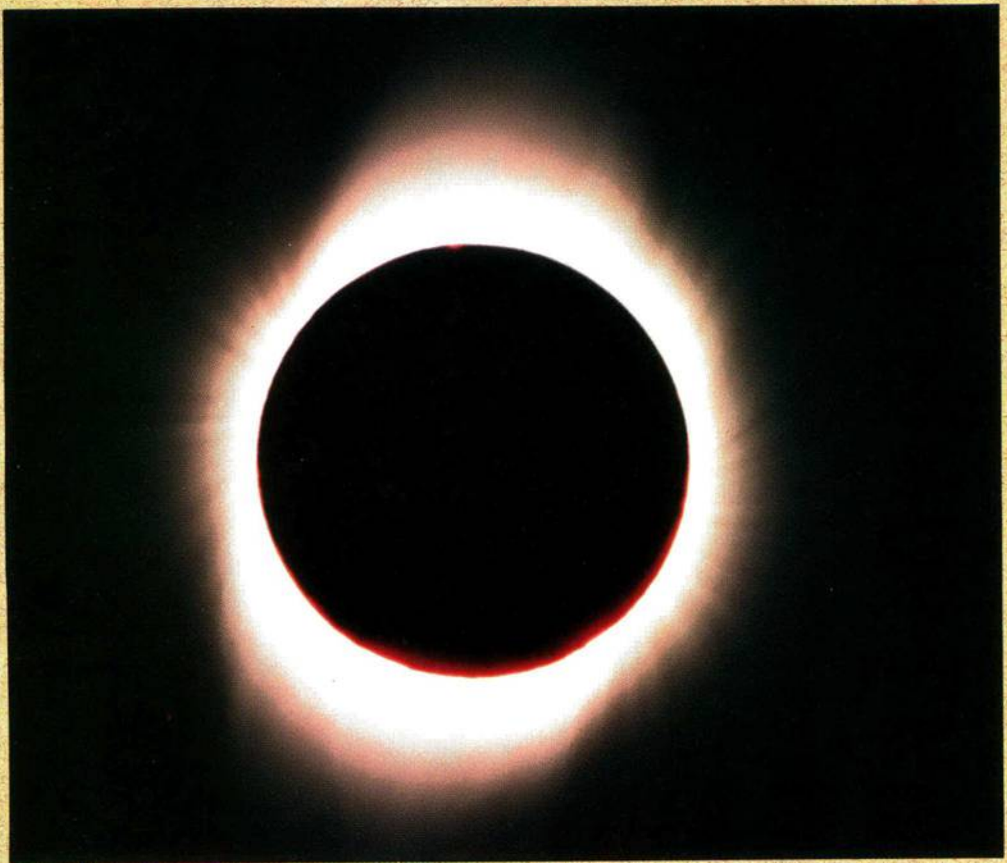
READER REPORTS

Eclipse Over the East

A total solar eclipse swept the Moon's shadow over the Middle East, parts of Russia, Asia, and Indonesia on the morning of October 24, 1995. Many observers traveled to locations in India to view the spectacle. Jay Pasachoff and a group of students from Williams College in Massachusetts set up shop at Mukandgarh Fort, Rajasthan, India, to conduct a series of experiments related to the Sun's corona.

The primary experiment was a search for the method by which the corona heats to 2 million K through a search for rapid (1-second) oscillations in the corona's green spectral line. Participants in the experiment included Bryce Babcock, Eric Kutner, Kevin Reardon, Sebastian Diaz, Rana Nichols-Kiley, and Jonathan Kern. A second expereiment created a map of the corona's temperature using a set of ultraviolet and polarizing filters. A complete report on the eclipse will appear in the April ASTRONOMY.

Saturn's Thin Rings. Phil Dombowski of Glastonbury, Connecticut, reports glimpsing thin "ring segments" on either side of Saturn's disk on June 18, 1995, using his 11-inch SCT. Dombrowski observed at 300x and described the ring segments as visible in transience, for a second or two out of every 30-second period. "I'm certain I observed the shadowed side of the rings," says Dombrowski. "I've made similar



October 24's Solar Eclipse

by Huguette Guertin
(700mm Maksutov-Cassegrain at f/8, ISO 25 film, 1-second exposure on October 24, 1995, taken from India)

Fire in the Indian Sky

by Jay Pasachoff and Rana Nichols-Kiley
(taken October 24, 1995, from Rajasthan, India)

Diamond Ring with Prominences

by Yves Delaye
(4-inch apochromatic refractor at f/10, Ektachrome 100 film, 1/500-second exposure taken on October 24, 1995, from Pehersar, India)

observations on two other mornings and again the ring segments appeared and then were gone as the seeing sharpened and dulled."

Leonids Disappoint and Alpha Monocerotids Outburst. "On the night of November 17/18, I began my meteor watch at 10 p.m. EST. Most of the night was uneventful." That comment from meteor watcher John C. Sellechio of Warwick, Rhode Island, sums up the somewhat disappointing performance of the 1995 Leonids. However, at 10:23 p.m., Sellechio and his wife saw a –5 to –7 magnitude fireball. "It was the best I've ever seen," he says. The little-known Alpha Monocerotid meteor shower, on the other hand, experienced an outburst on November 22, 1995. Observers from the Spanish Meteor Society recorded zenithal hourly rates equivalent to several hundred meteors per hour.

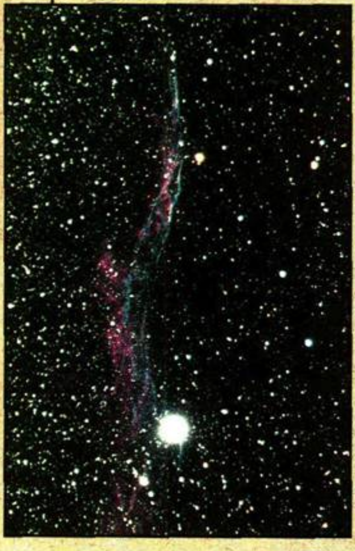
Surprise from Schwassmann-Wachmann 3. The old periodic comet Schwassmann-Wachmann 3 startled observers in early October 1995 when it erupted in a brightness outburst. Rather than hovering around 10th magnitude as it normally does, S-W 3 brightened to magnitude 5.5 by mid-month, becoming briefly visible to the naked eye.

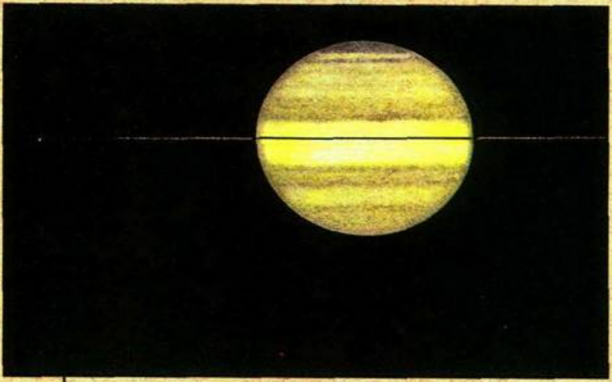
Numerous observers thought they had discovered a comet. Dale Johnson, an employee of the U.S. Embassy in Lusaka, Zambia, was one of them. Says he: "I accidentally picked it up while I was moving down the tail of Scorpius, checking some of the colorful features." ☐

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with name, address, and social security number. You may send written reports via the Internet to: rreports@astronomy.com

The Veil Nebula

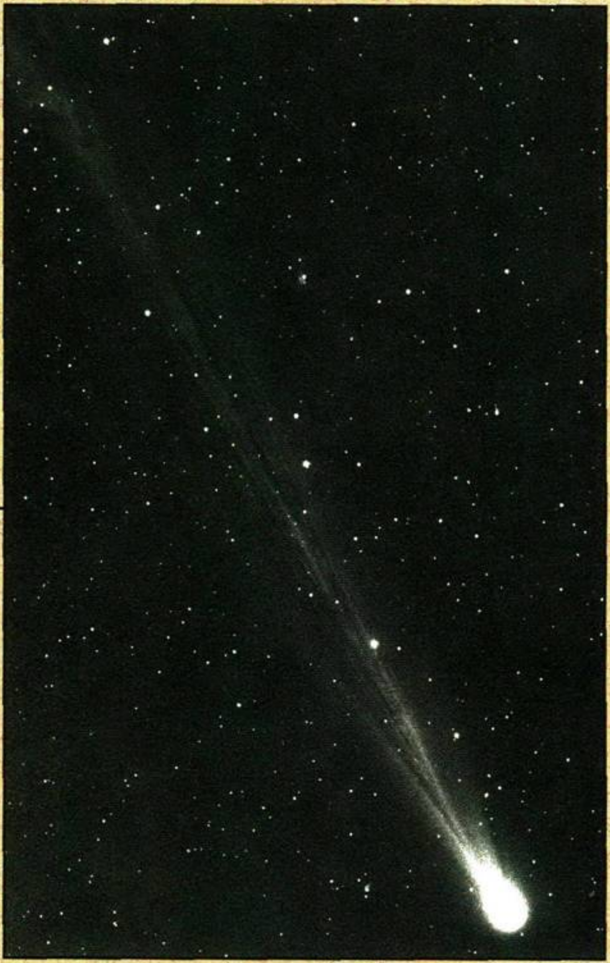
by Bob and Janice Fera
(11-inch SCT at f/10, hypersensitized Fuji Super G 800 film, composite of two 120-minute exposures)





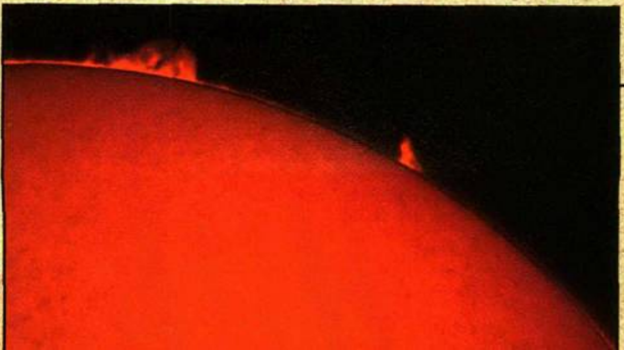
Saturn with Edge-on Rings and Mimas (left)

by Thomas A. Dobbins
(36-inch Crossley refractor at Lick Observatory operating at 588x and 1186x on August 11, 1995)



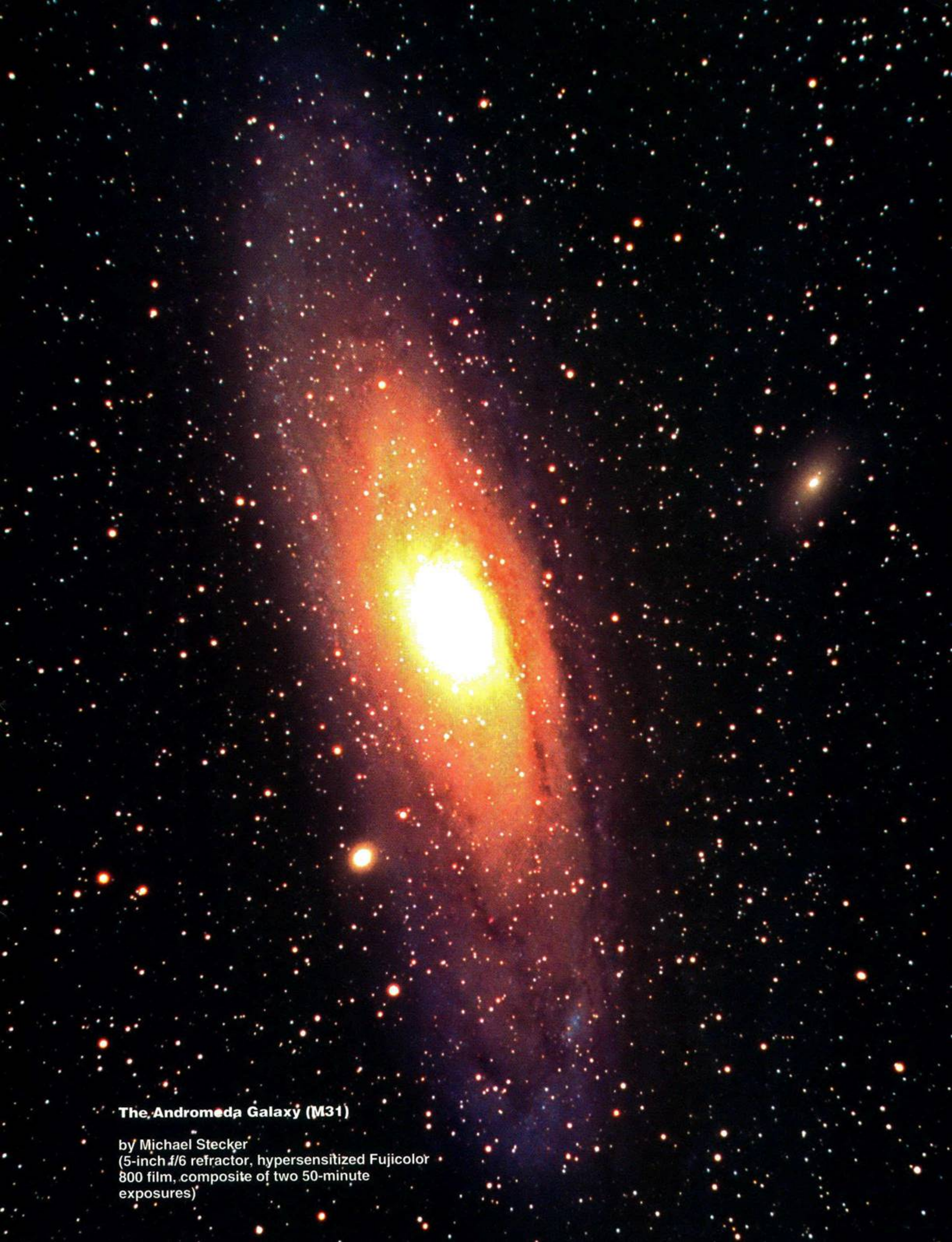
Comet De Vico

by Gerald Rhemann
(7.5-inch Schmidt camera at f/1.7, hypersensitized Tech Pan film, 4-minute exposure on October 5, 1995)



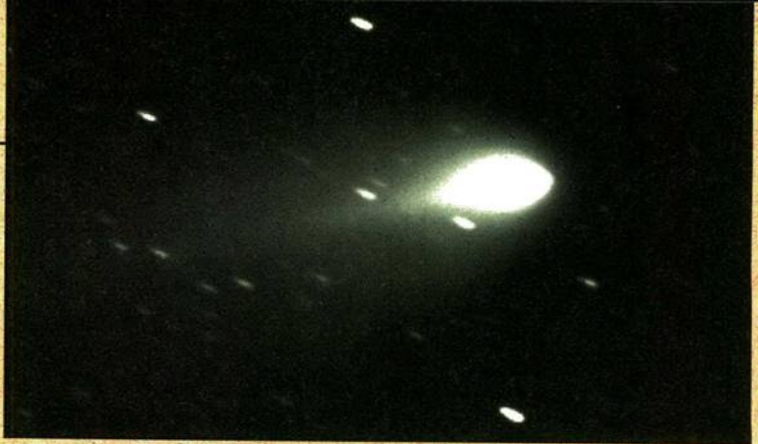
Solar Prominences in H-alpha

by H. J. P. Arnold
(hydrogen-alpha composite image taken August 10, 1995)



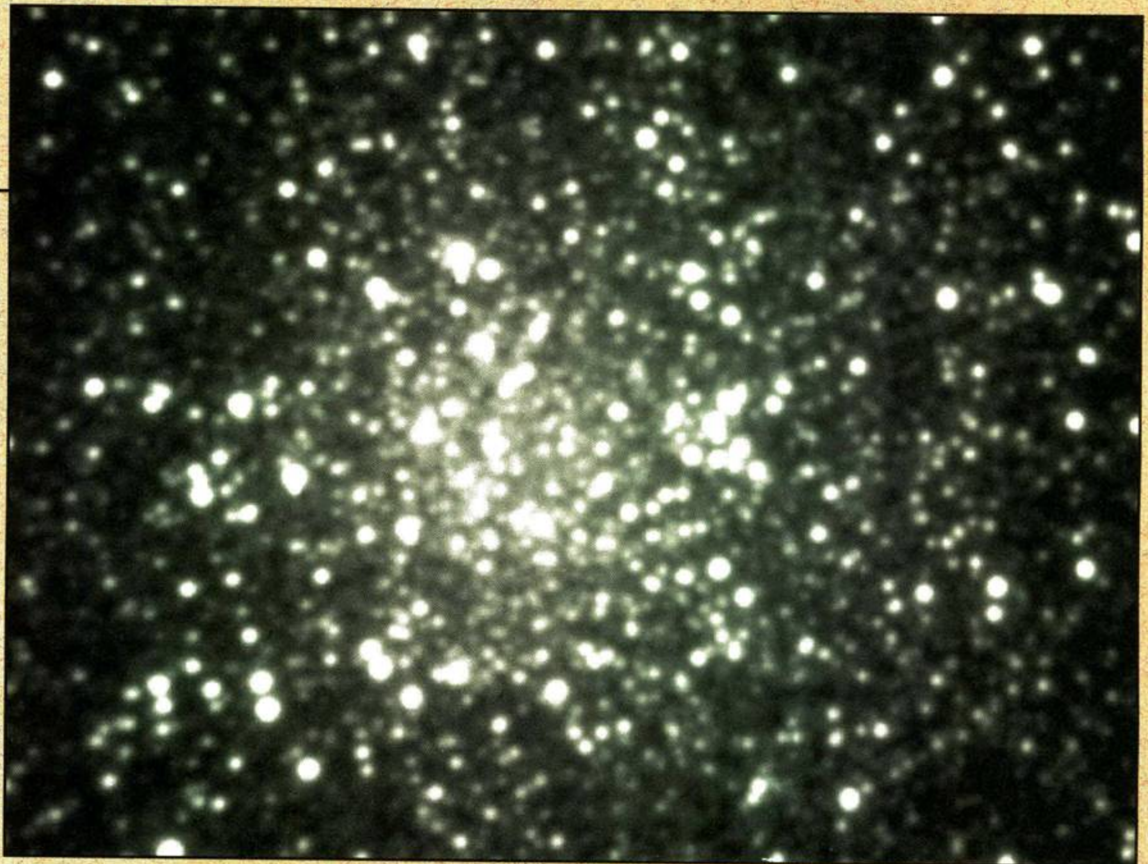
The Andromeda Galaxy (M31)

by Michael Stecker
(5-inch f/6 refractor, hypersensitized Fujicolor 800 film, composite of two 50-minute exposures)



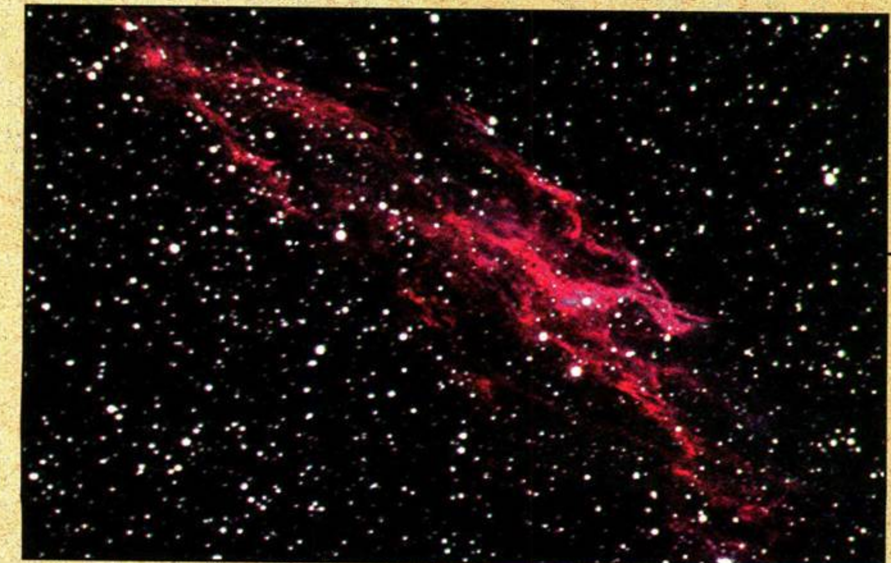
Comet Schwassmann-Wachmann 3

by Tim Puckett
(12-inch f/7 SCT, ST-6 CCD camera, 300-second exposure taken October 17, 1995)



Globular Cluster M22 in Sagittarius

by Al Kelly
(32-inch f/4 reflector, Cookbook 245 CCD camera, composite of three 15-second exposures)



The Veil Nebula

by Keith Snyder, Steve Messner, Bob Elliott, and Paul Nelson
(12-inch reflector, STAR I CCD camera, 160-second exposure)

Loop-Shaped Solar Prominence

by Giovanni dal Lago
(11-inch SCT at f/30, Starlight Xpress CCD camera, Daystar 0.6Å hydrogen-alpha filter, taken April 17, 1995)

Craters Eratosthenes and Stadius

by Gérard Therin
(10-inch SCT at f/38, Hi-Sis 22 CCD camera, 0.2-second exposure)

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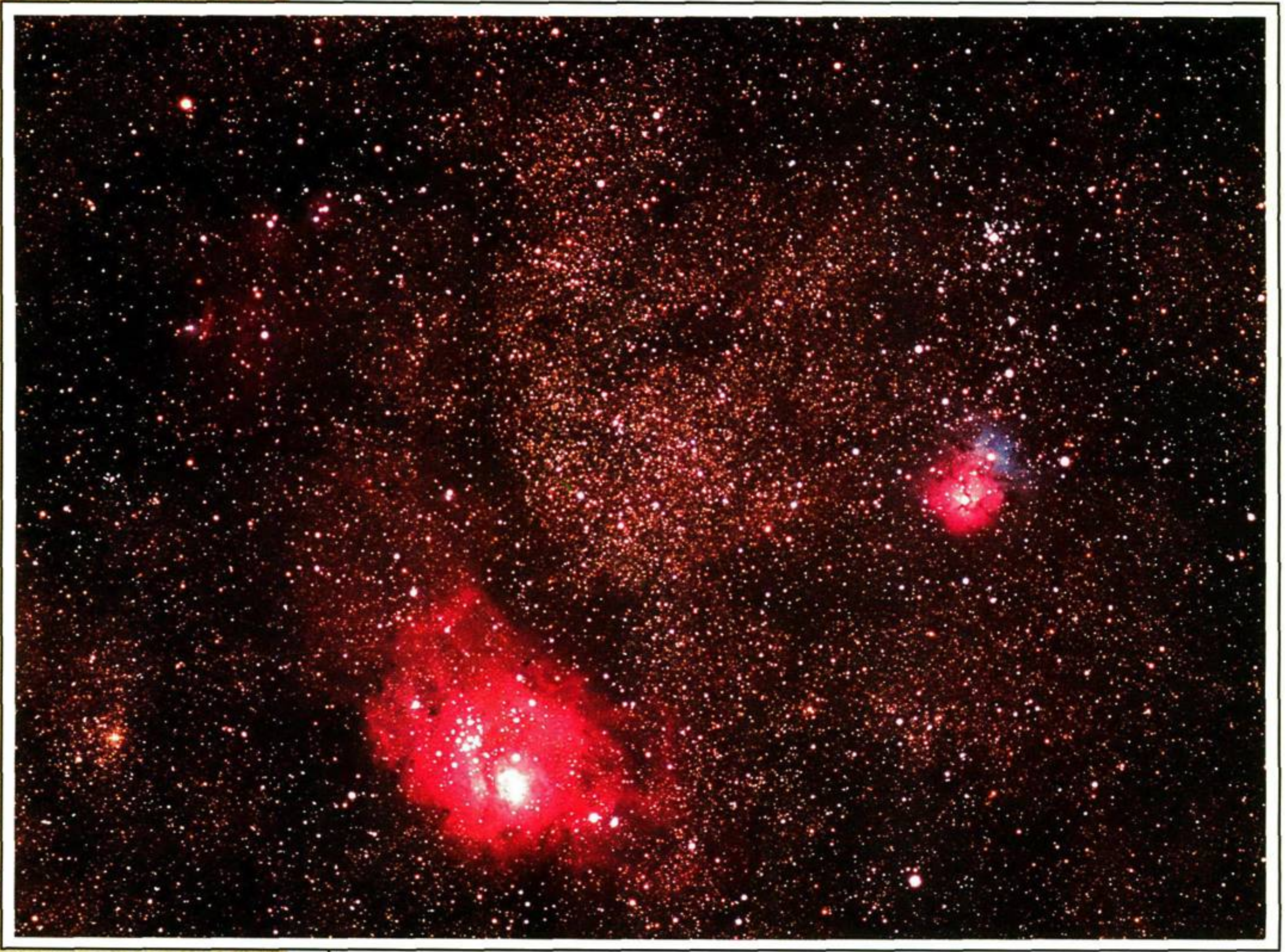

The Lagoon and Trifid Nebulae

by Vince and Maggie Farnsworth
(4-inch f/5 refractor, Fuji SG 800 film, composite of two 35-minute exposures)

"Maggie and I use modest equipment," says Vince Farnsworth. "This doesn't deter us from avidly pursuing the hobby; it's been almost two years since we took our first astrophoto and now we are thoroughly hooked. Capturing the beauty of the universe on film is almost like magic."

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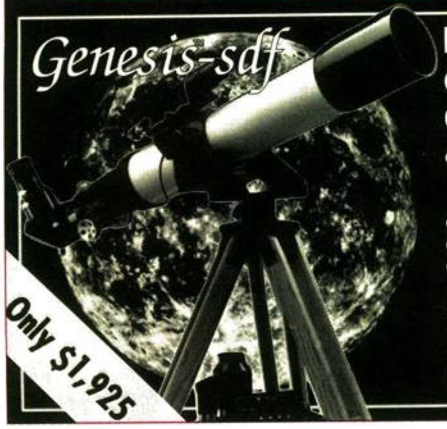

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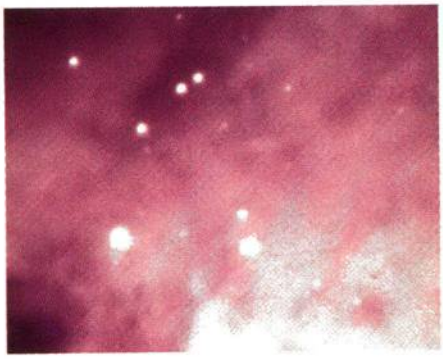

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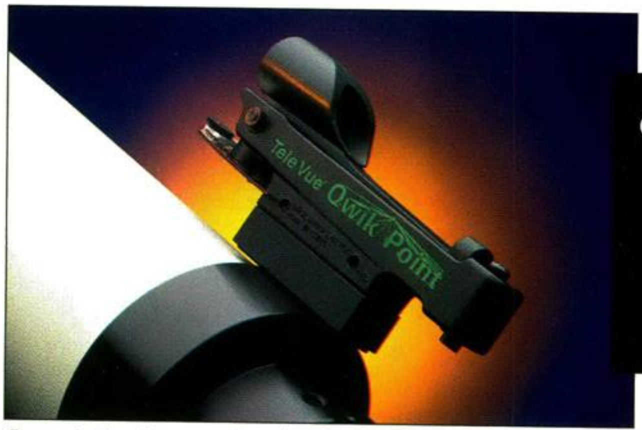

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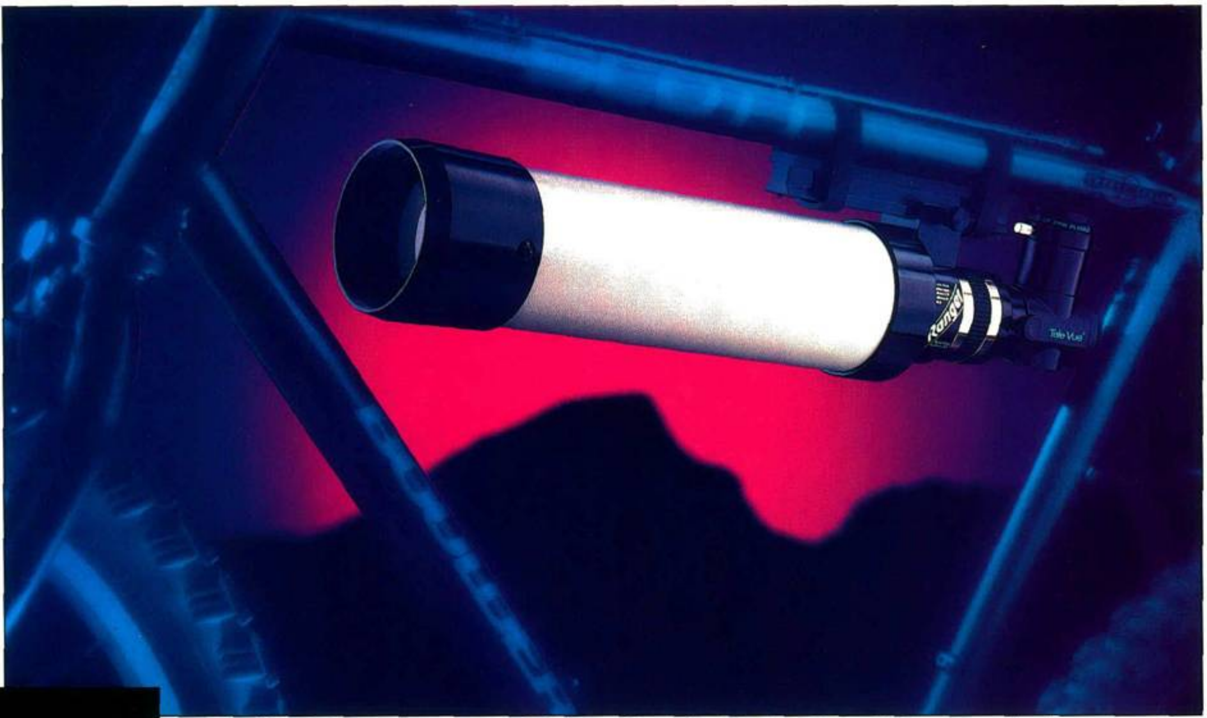

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